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BIRD USE OF ARCTIC COASTAL SHORELINES AT CANNING RIVER DELTA, ALASKA

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# BIRD USE OF ARCTIC COASTAL SHORELINES
# AT CANNING RIVER DELTA, ALASKA

A

THESIS

Presented to the Faculty of the University of Alaska
in Partial Fulfillment of the Requirements
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MASTER OF SCIENCE

By
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BIRD USE OF ARCTIC COASTAL SHORELINES
AT CANNING RIVER DELTA, ALASKA

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ABSTRACT

Due to the imminence of oil industry exploration and development along the Beaufort Sea shoreline, a study was made of bird use of coastal shorelines at Canning River Delta, in the Arctic National Wildlife Refuge, Alaska. Bird censuses were conducted along 27.5 km of shoreline transects at 4-day intervals from mid-June to early September 1980. Fifty-one species of local or migrating birds used shoreline habitats for feeding, resting, molting, or staging, with Oldsquaw the most abundant. Ten species nested on shorelines. Birds used shorelines most heavily from late July to early September. Flock size increased for most species as the summer progressed and peaked during fall migration. Six shoreline habitats were identified from an analysis of their relative use by birds. The most important bird habitats on Canning Delta shorelines were saline meadows, littoral flats, barrier islands (especially their tips and gaps between them), and the river mouth.

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## INTRODUCTION

Flat, frozen, snow-covered, and wind-swept throughout 8 months of the year, the Beaufort Sea Coast is nonetheless an important region for birdlife in Alaska. Numerous shorebirds migrate long distances to take advantage of the rich food source offered by the abundance of insect life emerging on the tundra during the brief arctic summer. The extensive areas of tundra ponds, lakes, and protected coastal lagoon systems provide habitat for nesting and molting waterfowl. Many other species use coastal areas for resting and feeding during their migrations to and from arctic Alaska. "During portions of the year, significant fractions of the total North American populations of a number of bird species are present in the nearshore waters of the Beaufort Sea" (Johnson and Richardson 1980:118), including Yellow-billed Loon (*Gavia adamsii*), Brant (*Branta bernicla*), Oldsquaw (*Clangula hyemalis*), Common Eider (*Somateria mollissima*), King Eider (*Somateria spectabilis*), Glaucous Gull (*Larus hyperboreus*), Sabine's Gull (*Xema sabini*), Arctic Tern (*Sterna paradisaea*), Red Phalarope (*Phalaropus fulicaria*), and Red-necked Phalarope (*Phalaropus lobatus*).

Johnson et al. (1975) and Johnson and Richardson (1980) have reviewed knowledge of birds found in the Beaufort Sea area, but many questions remain to be answered. In recent years oil industry exploration and development in the Arctic has provided both impetus and funding for numerous studies of Beaufort bird ecology and the potential impacts of development. The recent work of two research teams has been outstanding in focusing on bird use of Beaufort Sea shorelines, the important interface between land and water. Johnson and Richardson (1980) studied migration, nesting, molting, staging, feeding, and impacts of disturbance on birds using shorelines at Simpson Lagoon in 1977 and 1978. Connors and Risebrough (1976-81) focused on shorebird dependence on arctic littoral habitats at Barrow, Prudhoe Bay, and Harrison Bay.

Their research included studies of trophic relationships, microhabitat preferences, seasonal occurrence, diets, and descriptions of shorebird habitats.

The likelihood of imminent exploration and development of petroleum reserves in the Arctic National Wildlife Refuge prompted the U.S. Fish and Wildlife Service to initiate a 2-year study of bird use of the Canning River Delta area in 1979. The Canning River Delta, at the western edge of the Arctic National Wildlife Refuge on the Beaufort Sea coast, had been identified by U.S. Fish and Wildlife Service biologists as an area of relatively high bird use. Research at Canning Delta included studies of birds on tundra habitats, birds on shoreline habitats, and bird migration (Martin and Moitoret 1981). Field work for my thesis was conducted during the summer field season of 1980, with the following objectives:

1) to identify and describe coastal shoreline habitats and their use by birds;
2) to note how bird use of coastal shoreline areas was affected by season, weather, tide, ice and snow cover, geography, and other factors; and
3) to identify the most important shoreline habitats and seasons of use, in order to guide future management of the area.

## DESCRIPTION OF THE STUDY AREA

The study area was located in the vicinity of Brownlow Point (70°10'N, 145°50'W), approximately 85 km west of the village of Kaktovik (Barter Island) and 95 km east of Prudhoe Bay, on the northern coast of Alaska and the western boundary of the Arctic National Wildlife Refuge (Figures 1 and 2). At the Canning River Delta the Arctic Coastal Plain is much narrower than it is farther west at Prudhoe or Barrow. The Canning River emerges from the Saddlerochit Mountains in the Brooks Range and flows north across approximately 45 km of Arctic Coastal Plain before reaching the Beaufort Sea. Near the coast the Canning River fans into several distributaries, which give the delta a width of approximately 20 km along the coast. This study was conducted in the vicinity of the West Branch distributary of the Canning River, which enters the Beaufort Sea east of the Staines River, south of Flaxman Island, and just west of Brownlow Point.

The study area was underlain by a geological unit of unknown origin, described and named by Leffingwell (1919) as the "Flaxman Formation," which differs in lithology from the gravel of Brooks Range origin in alluvial fans (Hopkins and Hartz 1978). However, the surface appearance of the Canning Delta was typical of Arctic Coastal Plain topography in other localities. The delta contained extensive areas of low-lying polygonized tundra ranging 1.5 to 3.5 m above sea level and drier ridges and lakeshore bluffs reaching 7 to 10 m elevation. There was also a concentration of large lakes, which is atypical of most of the coastal plain within the Arctic National Wildlife Refuge, although similar to coastal areas to the west.

Like much of the northern coast of Alaska, the coastline in the Canning Delta area included a lagoon system partially enclosed by a series of barrier islands parallel to the coast. The geology and geomorphology of these barrier island-lagoon systems has been well described by Hopkins and Hartz (1978). West of Brownlow Point a short (1.5 km) sand and gravel spit was separated by 3 km from Flaxman Island. This

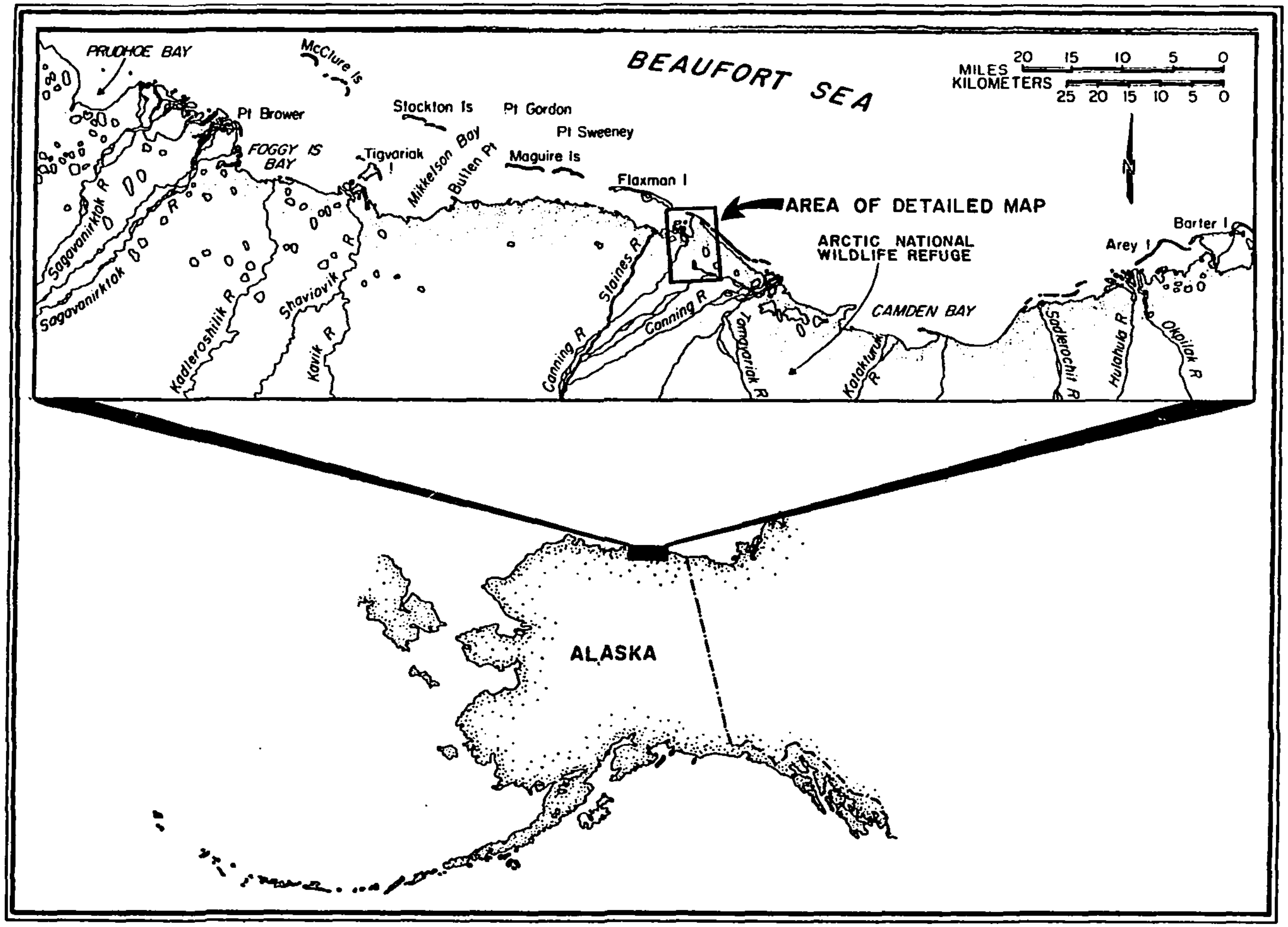


FIGURE 1. Map showing location of study area in relation to a portion of the Beaufort Sea coast and the state of Alaska.

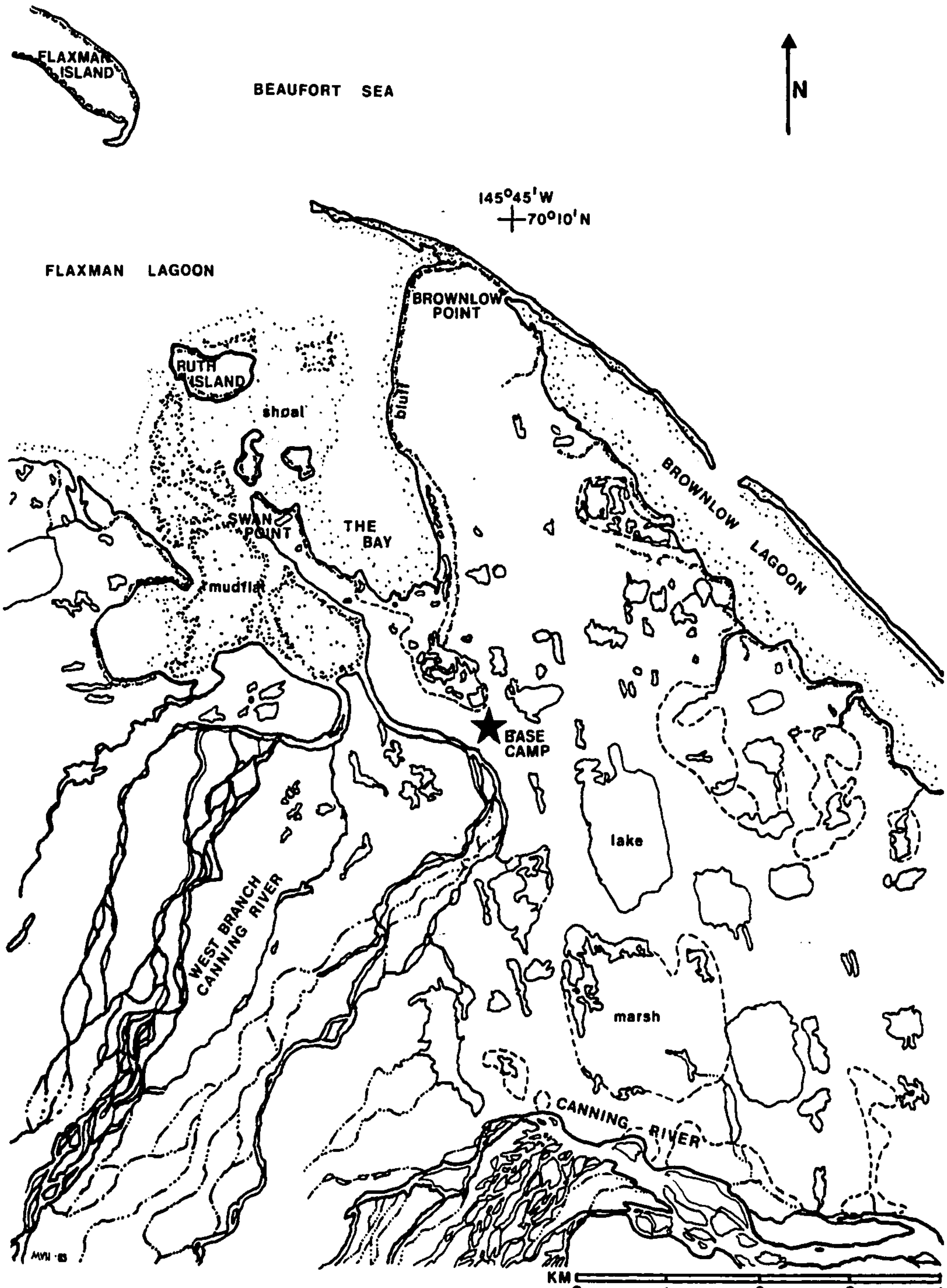


FIGURE 2. Map of study area, Canning River Delta, Alaska, 1980.

spit and island formed the outer edge of Flaxman Lagoon, a relatively wide (5 km) and deep (1-3 m) lagoon, with major connections to the Beaufort Sea. In contrast, the barrier island east of Brownlow Point stretched for approximately 12 km (interrupted by only one 100 m gap) to the mouth of the Canning River. It enclosed a long, narrow (less than 1 km), relatively shallow (1 m) lagoon (herein called Brownlow Lagoon), with limited connection to the Beaufort Sea.

The barrier islands in the Canning Delta region were typically low (less than 1 m), narrow (less than 100 m), and unvegetated. The mainland lagoon shorelines ranged from bluffs of 3 to 4 m in elevation, to low eroded mud banks which were periodically flooded by high tides, and low marshy saline meadow areas. Associated with the river mouth were sandy dune areas and extensive mudflats.

## METHODS

### FIELD METHODS

Field operations were conducted from 24 May through 9 September 1980 from a base camp on the east bank of the West Branch distributary of the Canning River, approximately 4 km from its mouth (Figure 3). Most survey areas were accessible by foot within a day's walk from the base camp. A small inflatable rubber boat with a 4.5 hp motor provided access to offshore islands.

Bird censuses were conducted at 4-day intervals from mid-June to the first week of September on 27.5 km of coastal shoreline. Ten transects were designated, each measured and marked at 100 m intervals with numbered stakes. For convenience, a descriptive name was given to each transect, and these are shown on Figure 3 with their respective lengths. Census of the barrier island transects did not begin until mid-July, due to difficulties of access.

A census was conducted by a single observer walking the length of the transect and recording all birds seen with 10X binoculars. When enough observers were available, all transects were walked on the same day to minimize the effect of weather and visibility variables when comparing transect data.

Transect censuses were generally conducted between 1000 and 1700, Alaska Standard Time, this being the time of optimal visibility on frequent days with morning fog. Before beginning each transect, the observer recorded data on weather, visibility, ice conditions, and tidal stage. The observer recorded time upon entering each 100 m subunit of a transect and then recorded all birds seen in that subunit by species, sex, age, number, and location. Notes were also made on the behavior of the birds and their flight direction if flying. Location was defined by the following zones:

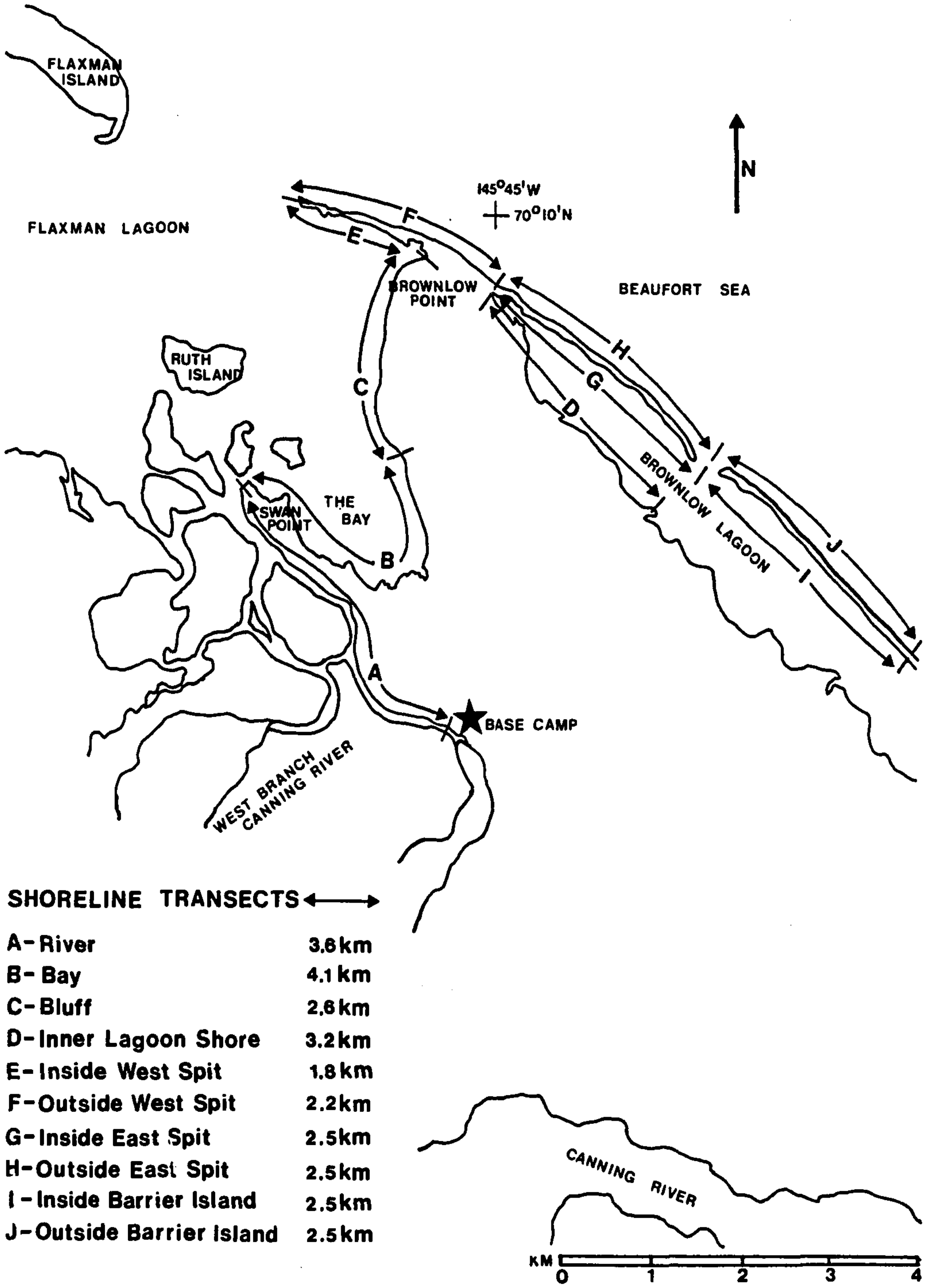


FIGURE 3. Map of study area and shoreline transects, Canning River Delta, Alaska, 1980.

1) On shore, within 50 m of water's edge

2) On bluff above shore, within 50 m of water's edge

3) On water, within 50 m of water's edge

4) On water, between 50 and 200 m of water's edge

5) On water, over 200 m from water's edge

6) Flying (Data on flying birds were used in an analysis of bird migration [Martin and Moitoret 1981] and are not included in the results reported here.)

These zones were chosen to correspond with the 50 m transect width used by Connors and Risebrough (1978) and with the 200 m transect width used in the U.S. Fish and Wildlife Service aerial lagoon surveys (Spindler 1981), so that comparisons could be made with these studies. If the same bird was observed subsequently in more than one zone or more than one subunit, only the first observation was recorded.

Censuses of Brownlow Lagoon were conducted on 22 July, 5 August, and 21 August 1980. These days had clear skies and calm waters, permitting safe boat travel and good visibility. One observer walked the length of the barrier islands, recording all birds seen on or outside the islands, while a second observer travelled by inflatable raft up the lagoon, recording all birds seen on the lagoon. Dates for these surveys were chosen to coincide with dates of aerial lagoon surveys conducted by Arctic National Wildlife Refuge personnel.

A qualitative habitat description was made of each 100 m subunit of each transect. Slope, aspect, topography, elevation change, substrate description, and estimates of percent vegetation cover by species were recorded. Water depth profiles were recorded along a line perpendicular to the shoreline at the center of each subunit. Depth measurements were taken at 5 m intervals up to 50 m from the shoreline, or until the water depth reached 75 cm (top of hip boots), whichever came first. Three water depth profiles were taken across Brownlow Lagoon from the boat. Offshore water depths were determined from depth profiles on U.S. Dept. of Commerce National Ocean Survey Nautical Chart #16045.

Temperature was recorded continually with a recording thermograph at the base camp. Wind direction and velocity were recorded twice daily with a Sims hand-held anemometer at the base camp. Sky condition and occurrence of precipitation were also recorded twice daily. A tide table for Flaxman Island for the summer of 1980 was obtained by making the appropriate transformations to the Kodiak tide tables (U.S. Dept. of Commerce 1980).

## DATA ANALYSIS

Information on habitat use by birds at Canning Delta was derived by subjecting the 1980 transect data to the TWINSPAN analysis of the Cornell Ecology Program Series (Hill 1979), a computer program for ordination of ecological data. This program performs a dichotomous-branching and clustering ordination of taxa and samples simultaneously, using the multivariate technique of reciprocal averaging (Hill 1973). This particular ordination program was chosen for its ease in handling large data sets with large numbers of zeros.

Birds were summed by species for each 500 m subunit of each transect for the entire summer. All birds were included in this analysis, whether they occurred on the shoreline or in the water within each subunit.

The resulting data array of 51 species x 54 subunits was subjected to the TWINSPAN analysis, which divided the data into two groups of subunits with a maximum difference in species composition. Each group was then further divided into two groups by the same process, and this procedure was repeated as many times as the results remained meaningful. Preferential and non-preferential species were given at each level of division. Preferential species were those that showed a significant association with one group and non-association with the other, while non-preferentials showed no significant association with either group. The purpose of this analysis was to test whether habitat units showing a significant difference in bird species composition could be recognized by visible physical differences.

Friedman tests (Conover 1980) were used to test the hypothesis that birds showed a differential distribution around gaps between barrier islands. Only Oldsquaw data were used, because this was the only species numerous enough and present for a sufficiently long time period to provide an adequate sample size. Oldsquaw counts on each census date were summed and then ranked for each 500 m subunit of each of the six barrier island transects. The null hypothesis was that the mean rank of any 500 m subunit would not differ significantly from the mean rank of any other 500 m subunit, throughout the summer; i.e., Oldsquaw distribution was random along each transect. The alternative hypothesis was that at least one 500 m subunit in any transect would yield a significantly higher mean rank than at least one other 500 m subunit.

Chi-Square tests (Conover 1980) were used to test the hypothesis that flock size changed seasonally. The study period was divided into four time periods: 1-24 June, 28 June-22 July, 24 July-14 August, 17 August-6 September. Each period included seven shoreline censuses, except the last which included six. Within each time period all birds observed of each species with an adequate sample size were summed within the following flock size categories: 1 bird, 2 birds, 3-10 birds, 11-50 birds, 51-100 birds, over 100 birds. Chi-Square tests for differences in probabilities were performed on the data matrices of time period x number of birds in each flock size category. The null hypothesis was that the distribution of birds in flock size categories was the same for all four time periods. The alternate hypothesis was that the distribution differed in at least two time periods.

## RESULTS AND DISCUSSION

### BIRD SPECIES USING CANNING RIVER DELTA SHORELINES

Pitelka (1974) listed 151 bird species, including 22 regular and 13 occasional breeders, from the Barrow region of the North Slope of Alaska. Bergman et al. (1977) recorded 72 bird species, including 25 breeders, during a 5-year study at Storkerson Point in the Prudhoe Bay area. At Canning Delta, 84 bird species were recorded in 2 years of study (Martin and Moitoret 1981), including 29 confirmed and 6 suspected breeders for a total of 35 breeding species. Thus, compared with Barrow, Canning Delta had fewer total species (probably due to the greater number of stragglers and accidentals reported at Barrow, and more years of observation) but an equal number of breeders. Compared with Storkerson Point, and probably most other Arctic Coastal Plain sites, Canning Delta was species rich. Factors contributing to this species richness included proximity to the mountains of the Brooks Range and the ecological diversity of river channels, bluffs, saline meadows, lakes, ponds, coastal lagoons, and mudflats found in the Canning Delta area.

Of the 84 bird species recorded in the Canning Delta study area, 59 (70%) were observed on the 1980 shoreline censuses. Table 1 shows presence or absence of each of these 59 species on each census, and thus shows a pattern of seasonal occurrence. (Refer to Table 1 for scientific names of all bird species mentioned hereafter.) Fifty-one species were actually observed using land or water habitats on Canning Delta shoreline censuses. The mean number of birds of each species per kilometer averaged over all census dates for the 1980 season is shown in Table 2, which ranks the birds from most to least abundant.

Oldsquaw was by far the most common species observed on shoreline transects (Table 2); Oldsquaw were almost twenty times as numerous as birds of the three next most abundant species: Lapland Longspur, Semipalmated Sandpiper, and Red-necked Phalarope, all of which had average frequencies of at least 1/km. Birds of these three species were twice as common as Snow Buntings, Glaucous Gulls, Red Phalaropes, and

TABLE 1. Presence/absence of bird species on 1980 shoreline censuses, Canning River Delta, Alaska. 0 = species not observed; ◓ = species observed flying only; ◒ = species observed on shore or water only; ● = species observed both on shore or water and flying.

| Species | Jun | Jul | Aug | Sep |
|---|---|---|---|---|
| Red-throated Loon *(Gavia stellata)* | 00●◒●●◒ | ●◒●◓●●● | ●●●●●●● | ●● |
| Arctic Loon *(Gavia arctica)* | ●●●●●●● | ●●●●●●● | ●●●●●●● | ●● |
| Yellow-billed Loon *(Gavia adamsii)* | 0000000 | 00000◒● | 0◒00◓◒0 | 00 |
| Tundra Swan *(Cygnus columbianus)* | ◒◒◒◒◒◒◒ | ◒◒◒◒000 | 000◒◒0◓ | 0◓ |
| Greater White-fronted Goose *(Anser albifrons)* | ●◓0◓000 | 0000000 | 0000●00 | 00 |
| Snow Goose *(Chen caerulescens)* | ◓◓000◓0 | 0000000 | 000000◒ | 00 |
| Brant *(Branta bernicla)* | ●◓◓◓◓0◓ | ●●000◒0 | ◓000◓●● | ●● |
| Canada Goose *(Branta canadensis)* | ●◓◓0◒●◒ | ●●00000 | 00000◒◒ | 00 |
| Green-winged Teal *(Anas crecca)* | ◓000000 | 0000000 | 0000000 | 00 |
| Mallard *(Anas platyrhynchos)* | ◒000000 | 00000◒0 | 0000000 | 00 |
| Northern Pintail *(Anas acuta)* | ●●●●◓◒◒ | ●◒00●●● | ◒●●●●●0 | ●● |
| Northern Shoveler *(Anas clypeata)* | 0000000 | 0000000 | 000◓000 | 00 |
| Gadwall *(Anas strepera)* | ◒000000 | 0000000 | 0000000 | 00 |
| American Wigeon *(Anas americana)* | ◒◒●0◓00 | 0000000 | 00000◓0 | 00 |
| Greater Scaup *(Aythya marila)* | 0000000 | 0000000 | 00000◓0 | 00 |
| Common Eider *(Somateria mollissima)* | ◓●◓●●0◒ | ●◓●●●●● | ●●◓0000 | 00 |
| King Eider *(Somateria spectabilis)* | ◒●●●●◒● | ●00●◒●0 | ◓0◓0000 | ◒◒ |
| Oldsquaw *(Clangula hyemalis)* | ●●●●●●● | ●●●●●●● | ●●●●●●● | ●● |
| Black Scoter *(Melanitta nigra)* | 00000◓0 | 0000000 | 0000000 | 00 |
| Surf Scoter *(Melanitta perspicillata)* | 0000◒◓◓ | ◓0◒0000 | 00◓0000 | 00 |
| White-winged Scoter *(Melanitta fusca)* | 0000000 | 0●◓◒0◓0 | 0000000 | 00 |
| Red-breasted Merganser *(Mergus serrator)* | 0000●●◒ | ◒●●●◒◓◓ | ◒00◒0◒0 | ◒◓ |

TABLE 1. (contd.)

| Species | Jun | Jul | Aug | Sep |
|---|---|---|---|---|
| Peregrine Falcon *(Falco peregrinus)* | ◓000◓◓0 | 0000000 | 0000◓◓◓ | 00 |
| Gyrfalcon *(Falco rusticolus)* | 0000000 | 0000000 | ◓0◓0000 | ◒0 |
| Willow Ptarmigan *(Lagopus lagopus)* | 000000◒ | 0000000 | 0000000 | 00 |
| Rock Ptarmigan *(Lagopus mutus)* | ◒◒◒◒◒◒◒ | ◒◒◒◒◒00 | 00◒0◒00 | ◒0 |
| Black-bellied Plover *(Pluvialis squatarola)* | 0000000 | 0◒0◒0●● | ●●●0◒◒◒ | ◒◒ |
| Lesser Golden-Plover *(Pluvialis dominica)* | ◒◒●◒◓◒◒ | ◒◒◒●●●◒ | ●◓0●●●0 | 00 |
| Bar-tailed Godwit *(Limosa lapponica)* | ◒000000 | 0000000 | 0000000 | 00 |
| Ruddy Turnstone *(Arenaria interpres)* | ◒◒●◒◒●◒ | ◒●◒●●◒● | ●●●◒●●◒ | 00 |
| Red Knot *(Calidris canutus)* | 0000000 | 0000000 | 00000◒0 | 00 |
| Sanderling *(Calidris alba)* | ◒000000 | 0000000 | 00◓0◓●● | ●● |
| Semipalmated Sandpiper *(Calidris pusilla)* | ◒●●●●●◒ | ◒◒◒0◒◒◒ | ●●●◒◒◒0 | 00 |
| Western Sandpiper *(Calidris mauri)* | 0000000 | 0000000 | 000◒◒◒0 | 00 |
| White-rumped Sandpiper *(Calidris fuscicollis)* | ◒000000 | 0000◒◒0 | 00●●●00 | 00 |
| Baird's Sandpiper *(Calidris bairdii)* | ◒◒●●●◒● | ●●●●●●◒ | ●●◒◒◒◒0 | 00 |
| Pectoral Sandpiper *(Calidris melanotos)* | ◓0◒◒◓◒0 | ◒◒●0◒◓0 | ◓0◒●0●● | ◒0 |
| Dunlin *(Calidris alpina)* | ●0◒0◓00 | ●000◒◒◒ | ◒●●●●●● | ●◒ |
| Stilt Sandpiper *(Calidris himantopus)* | 0000000 | 0000000 | 0◒◒0◒0◓ | ◒0 |
| Buff-breasted Sandpiper *(Tryngites subruficollis)* | 0000●◒0 | 0◒◒◒◒◒◒ | 0◒◒◒◒◒0 | 00 |
| Long-billed Dowitcher *(Limnodromus scolopaceus)* | 0000000 | 0000000 | 00000◓◓ | ◒0 |
| Red-necked Phalarope *(Phalaropus lobatus)* | 0◒●◓0◒◒ | ◒◒◓00●◒ | ●●●●●●◓ | ●◒ |
| Red Phalarope *(Phalaropus fulicaria)* | 0◒0●●◒◓ | ◒0◒0◒◒● | ◓●●●◒●0 | ●◒ |

TABLE 1. (contd.)

| Species | Jun | Jul | Aug | Sep |
|---|---|---|---|---|
| Pomarine Jaeger *(Stercorarius pomarinus)* | ◓◓◓○◓○○ | ◓○○◓◓○○ | ○○○○○○○ | ◓○ |
| Parasitic Jaeger *(Stercorarius parasiticus)* | ◓◓○○◓◓● | ◓◓●◓◓○◓ | ◓○◓◓◓◓◓ | ◓◒ |
| Long-tailed Jaeger *(Stercorarius longicaudus)* | ◓○◓◓◓○◓ | ○○◓◓○○○ | ◓○◓○○○○ | ○○ |
| Glaucous Gull *(Larus hyperboreus)* | ◓●●●●●● | ●●●●●●◓ | ●●●●●●● | ●● |
| Black-legged Kittiwake *(Rissa tridactyla)* | ○○○○○○○ | ○○○○○○○ | ○○○○○○○ | ●○ |
| Sabine's Gull *(Xema sabini)* | ○◒○◒●●○ | ◒◓○○◒○○ | ○○●●◒○○ | ○○ |
| Arctic Tern *(Sterna paradisaea)* | ◓◒●●●●● | ●●●●●●● | ●●●●●◓◒ | ◒◒ |
| Black Guillemot *(Cepphus grylle)* | ○○○◒○○○ | ◓◒○●◒●◒ | ●●●◒●○◒ | ○○ |
| Snowy Owl *(Nyctea scandiaca)* | ○○○○◒○◒ | ○○○◒○○○ | ○○○○○○○ | ○○ |
| Short-eared Owl *(Asio flammeus)* | ◓◒○○○○○ | ○○○○○○○ | ○○○○○○○ | ○○ |
| *(Empidonax sp.)* | ○○○◒○○○ | ○○○○○○○ | ○○○○○○○ | ○○ |
| Common Raven *(Corvus corax)* | ○○○○○◓○ | ○○○○○○○ | ○○○○○◓○ | ○◓ |
| White-throated Sparrow *(Zonotrichia albicollis)* | ○○○○○○○ | ○○○○○○○ | ○○◒○◒○○ | ○○ |
| Lapland Longspur *(Calcarius lapponicus)* | ◒●◒◒◒◒● | ◒◒◒●◒◒◒ | ●◒◒●◒◒◒ | ●◒ |
| Snow Bunting *(Plectrophenax nivalis)* | ◒◒●◒◒◒● | ●◒◒◒●◒◒ | ◒●◒◒◒◒● | ◒● |
| Common/Hoary Redpoll *(Carduelis flammea/ C. hornemanni)* | ○◒○◓◓◓◓ | ○○○○○○○ | ○○○○○○○ | ○○ |

TABLE 2. Mean number of birds per kilometer on shoreline transects, averaged over all shoreline censuses for summer 1980 at Canning River Delta, Alaska; species listed in order of abundance; * indicates fewer than 0.1 birds per kilometer.

| Species | Birds/km | Species | Birds/km |
|---|---|---|---|
| Oldsquaw | 20.2 | Greater White-fronted Goose | 0.1 |
| Lapland Longspur | 1.3 | Buff-breasted Sandpiper | 0.1 |
| Semipalmated Sandpiper | 1.2 | Sabine's Gull | 0.1 |
| Red-necked Phalarope | 1.0 | Surf Scoter | 0.1 |
| Snow Bunting | 0.6 | White-rumped Sandpiper | 0.1 |
| Glaucous Gull | 0.5 | Stilt Sandpiper | * |
| Red Phalarope | 0.5 | Western Sandpiper | * |
| Northern Pintail | 0.5 | Snow Goose | * |
| Sanderling | 0.4 | Common/Hoary Redpoll | * |
| Arctic Tern | 0.4 | American Wigeon | * |
| Brant | 0.4 | Yellow-billed Loon | * |
| Baird's Sandpiper | 0.4 | White-winged Scoter | * |
| Arctic Loon | 0.4 | Long-billed Dowitcher | * |
| Dunlin | 0.3 | Black-legged Kittiwake | * |
| Ruddy Turnstone | 0.3 | Snowy Owl | * |
| King Eider | 0.2 | Parasitic Jaeger | * |
| Red-throated Loon | 0.2 | Red Knot | * |
| Common Eider | 0.2 | Willow Ptarmigan | * |
| Canada Goose | 0.2 | White-throated Sparrow | * |
| Red-breasted Merganser | 0.2 | *Empidonax* sp. | * |
| Lesser Golden-Plover | 0.2 | Mallard | * |
| Pectoral Sandpiper | 0.2 | Gadwall | * |
| Rock Ptarmigan | 0.1 | Bar-tailed Godwit | * |
| Black Guillemot | 0.1 | Short-eared Owl | * |
| Tundra Swan | 0.1 | Gyrfalcon | * |
| Black-bellied Plover | 0.1 | | |

Northern Pintails, which all had average frequencies of at least 0.5/km. An additional 14 species were fairly common on Canning Delta shorelines, with average frequencies of greater than 0.1/km; the remaining 29 species occurred with average frequencies of 0.1/km or less (Table 2). These figures represent an average over an entire summer, so short-term fluctuations in abundance are obscured.

## SEASONAL CHANGES IN BIRD USE OF CANNING RIVER DELTA SHORELINES

### Changes in Species and Numbers

The seasonal pattern of bird use of coastal shoreline habitat at Canning Delta can be described in two words: rapid change. Though separated in time by only 4 days, two successive shoreline censuses seldom yielded similar results in bird species and densities.

Only a few species were regularly present on shoreline transects throughout the entire summer (Table 1): Arctic and Red-throated loons, Northern Pintail, Oldsquaw, Glaucous Gull, Arctic Tern, Lapland Longspur, and Snow Bunting. A few additional species were regularly present, disappearing only at summer's end: Common Eider, Ruddy Turnstone, Lesser Golden-Plover, Baird's and Semipalmated sandpipers. Less common but frequently seen throughout the summer were Tundra Swan, King Eider, Red-breasted Merganser, Rock Ptarmigan, Buff-breasted Sandpiper, Parasitic Jaeger, Sabine's Gull, and Black Guillemot. Some birds were seen sporadically throughout the summer but were abundant during their fall migration: Pectoral Sandpiper, Dunlin, and Red and Red-necked phalaropes. Others were seen only during migration: Brant, Greater White-fronted Goose, White-winged and Surf scoters, Black-bellied Plover, White-rumped, Stilt, and Western sandpipers, Long-billed Dowitcher, and Sanderling. Of the remaining species, some were resident but rare, and others were accidental during migration.

Changes in intensity of use of Canning Delta shorelines by five major bird species groups during the summer of 1980 are illustrated in Figure 4. Numerical data from which this figure was derived are listed in Appendix 1.

Birds began arriving at Canning Delta in large numbers in late May and early June 1980. Arrival was a rapid and dramatic event, with the major influx occurring on a few days of favorable winds. Spring migration at Canning Delta peaked on 30 May and 5 June 1980 (Figure 5). Brant, Oldsquaw, and jaegers were observed flying eastward during spring migration (Figure 5), but direction of shorebird migration could not be

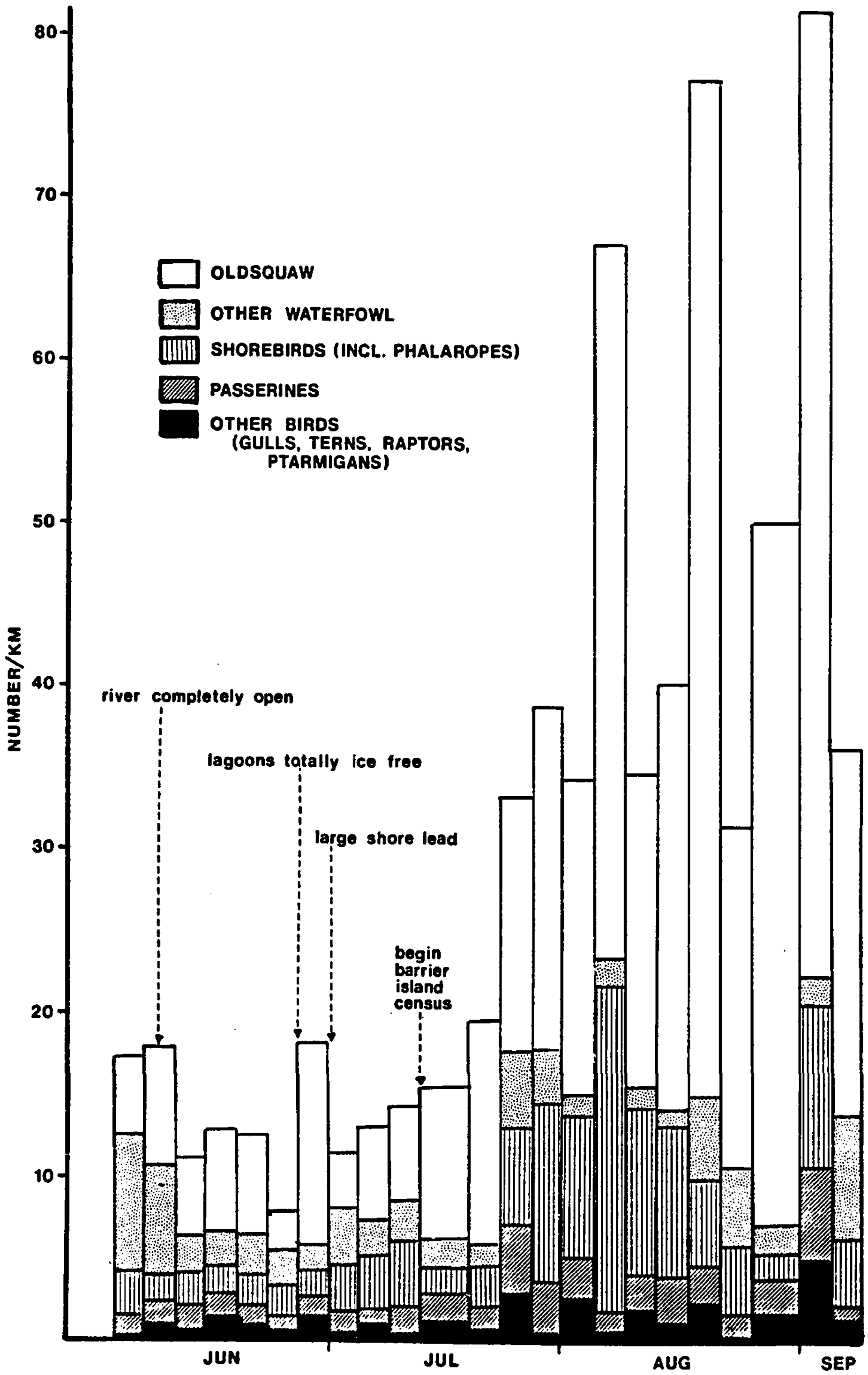


FIGURE 4. Total number of birds per kilometer on 1980 shoreline censuses at Canning River Delta, Alaska.

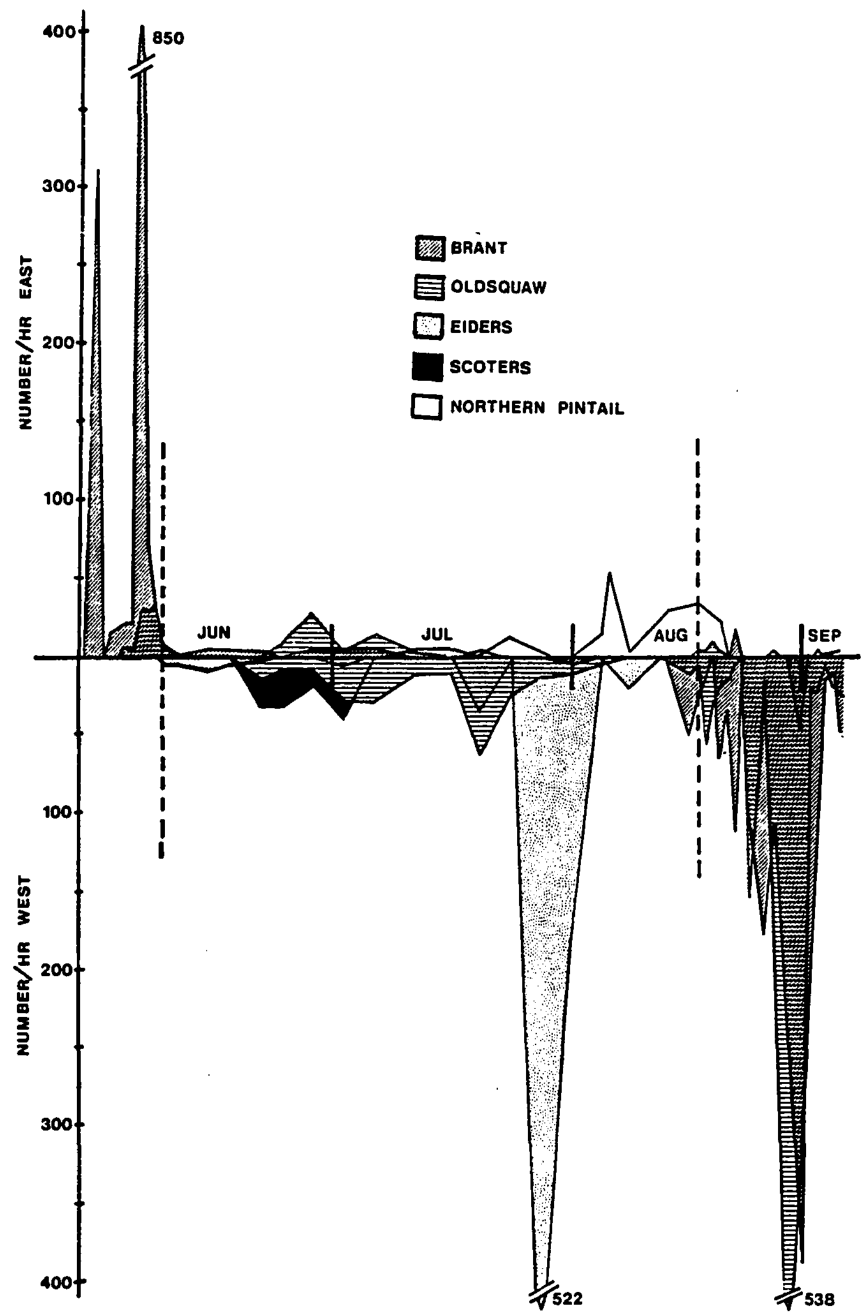


FIGURE 5. Graph of 1980 migration data for five waterfowl species at Canning River Delta, Alaska (from Martin and Moitoret 1981).

noted. From radar studies at Simpson Lagoon, Richardson and Johnson (1981) suggested that spring waterfowl migration was primarily eastward along the Beaufort Sea, while most shorebirds moved westward.

Birds did not make extensive use of shoreline areas during spring migration, because most shorelines were still covered by landfast ice. However, flocks of migrating waterfowl (Brant, Northern Pintail, American Wigeon, King Eider) were seen in and adjacent to the West Branch Canning River, which provided the only open water. According to Richardson and Johnson (1981) most eastward migration along the northeast Alaskan coast is broad-front in nature, with little coastal concentration. They suggested that most eiders and probably most Oldsquaw fly offshore where there is more open water, but they observed Brant flying more over the mainland at Simpson Lagoon. Observations of spring migration at Canning Delta supported this hypothesis, as the only spring migrant observed in large numbers from our base camp was Brant (Figure 5).

During late June and early July, bird numbers along shorelines were generally low (Figure 4), as most birds were nesting on the tundra. Low numbers of resident shorebirds and passerines fed along shorelines, however, and Oldsquaw were always present near the barrier islands. Geese were absent along coastal shorelines after mid-July, until their fall migration. Loons nested on tundra lakes and ponds but flew to the shoreline to feed in the lagoons or Beaufort Sea. They were seen with much lower frequency along shorelines during their incubation period (Figure 6). A midsummer westward molt migration of scoters along the Beaufort coastline has been documented by Johnson and Richardson (1982). At Canning Delta in 1980 a westward migration of scoters occurred in late June and early July (Figure 5), but only a few flocks stopped to rest or feed along the shorelines. A noticeable westward movement of Oldsquaw began in July (Figure 5) in conjunction with a gradual increase in Oldsquaw numbers along barrier island transects (Figure 7). Johnson and Richardson (1982) also described the movement of male Oldsquaw

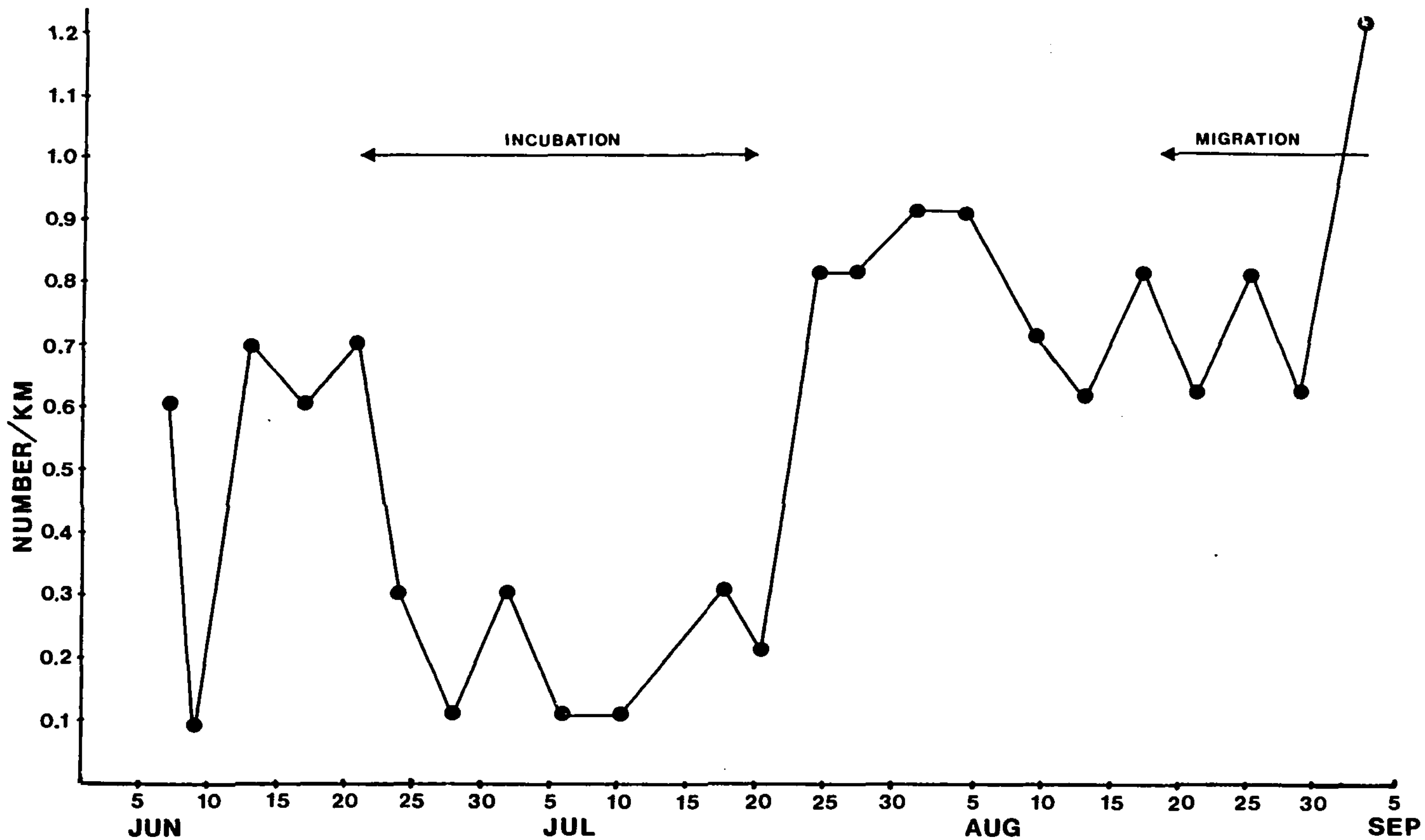


FIGURE 6. Number of loons per kilometer on 1980 shoreline censuses at Canning River Delta, Alaska.

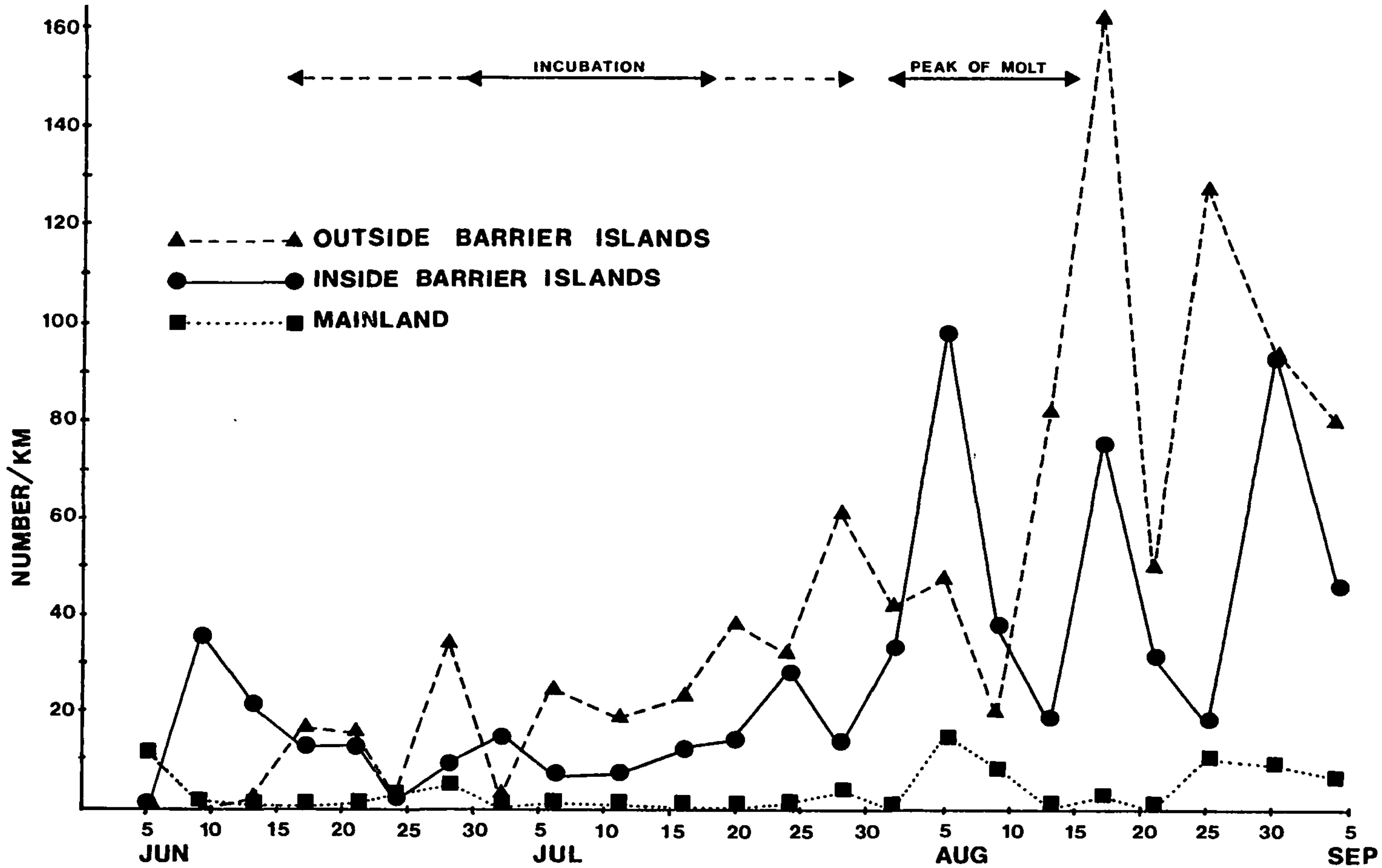


FIGURE 7. Number of Oldsquaw per kilometer on 1980 shoreline censuses at Canning River Delta, Alaska.

(along with non-breeders and failed breeders) westward along the Beaufort coast, where the birds concentrated in lagoons for their molt.

In late July and early August, the termination of nesting brought a dramatic increase of shorebirds and passerines to lowland and coastal sites (Figure 8). The influx probably included birds from inland sites moving to coastal areas to feed prior to migration (Martin and Moitoret 1981). The peak of migrating Red and Red-necked phalaropes was especially noticeable on barrier island transects in early August, as were large numbers of Semipalmated Sandpipers, Pectoral Sandpipers, and Lapland Longspurs in the saline meadow area of the bay transect from late July through early August. Migrating Black-bellied Plovers also began appearing along mainland shorelines in late July. Loons became more abundant along shorelines in late July as they began making more frequent trips to feed their young (Figure 6). A westward molt migration of (predominantly) male Common Eiders occurred in late July (Figure 5), but these birds seldom stopped to use shoreline areas. An increase of Northern Pintails feeding on saline meadows and ponds near the shoreline occurred during their eastward migration, from late July through August (Figure 5). An absence of flying Oldsquaw (Figure 5) indicated that Oldsquaw wing molt peaked at Canning Delta in 1980 during the first 2 weeks of August. Oldsquaw were more numerous outside the barrier islands than inside, except during their molt, when they were more concentrated in the lagoons (Figure 7). Aerial surveys (Spindler 1981) showed Oldsquaw to be more numerous inside the barrier islands than outside throughout the summer in most lagoons of the Arctic National Wildlife Refuge. The narrow and shallow configuration of Brownlow Lagoon may have made it less productive in available food than other lagoons studied by Spindler.

From late August to early September, shorebird numbers along shorelines declined, then showed another peak (particularly on barrier island transects) with the westward fall migration of Sanderling and (in lesser numbers) Dunlin (Figure 8). Small numbers of migrating White-rumped, Stilt, and Western sandpipers, and Long-billed Dowitchers were

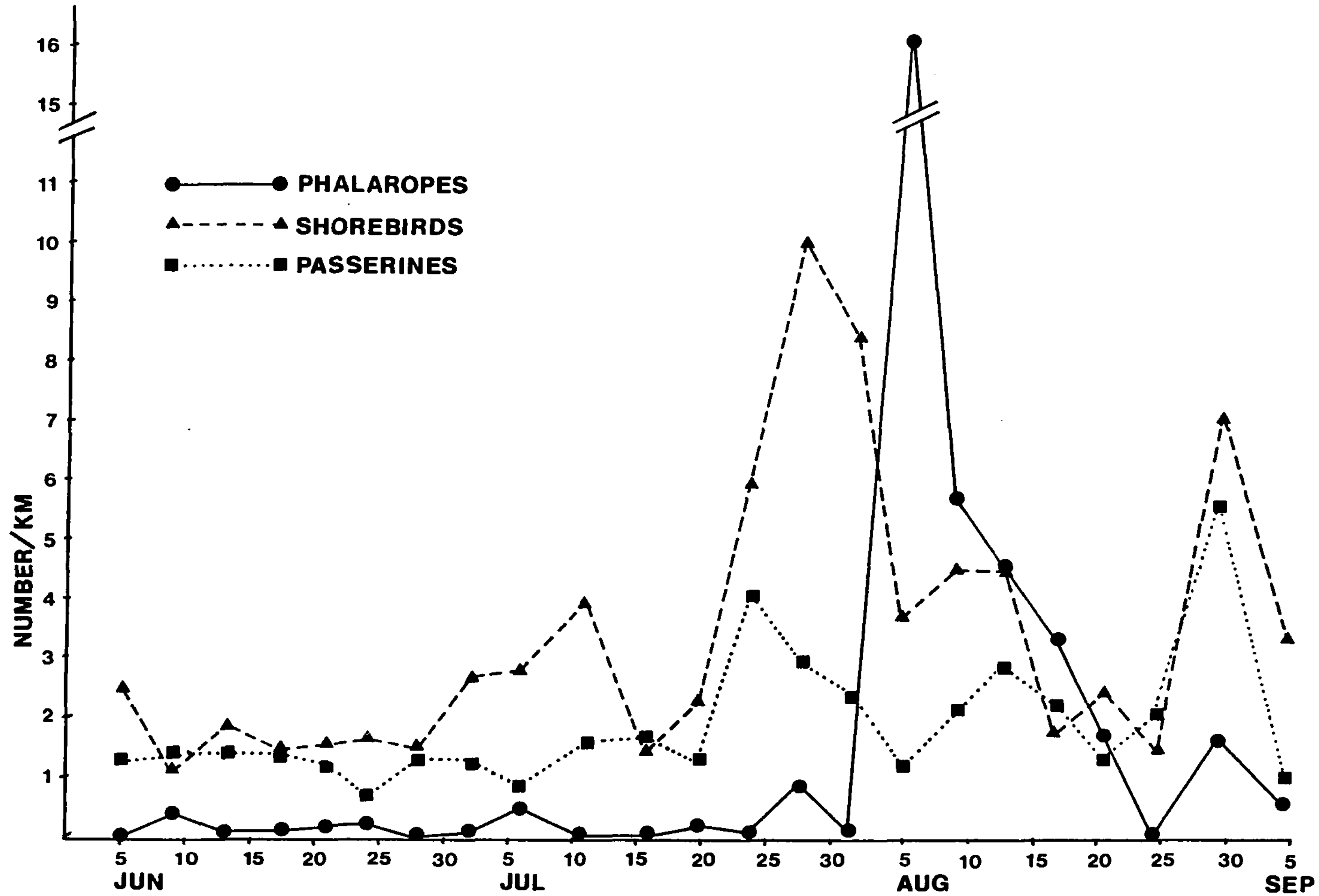


FIGURE 8. Number of phalaropes, shorebirds, and passerines per kilometer on 1980 shoreline censuses at Canning River Delta, Alaska.

also present along mainland shorelines at this time. Oldsquaw numbers remained high through early September, as they began their fall migration (Figure 7). Brant and other geese began appearing along shorelines in late August, as migrant flocks stopped to feed in saline meadow areas. Fall migration of both shorebirds and waterfowl was a more gradual event than spring migration and was more concentrated along the coastline.

By early September, bird numbers were low on mainland shorelines. Most shorebirds and passerines had departed, except for a few migrant Sanderling and Dunlin along the barrier islands. Oldsquaw, loons, and Glaucous Gulls were still abundant along the barrier islands, however, and Brant were still migrating along the mainland shoreline.

## Changes in Flock Size

In addition to seasonal changes in numbers of birds, there were also changes in the proportions of birds observed singly, in pairs, or in groups of various sizes throughout the summer. Chi-Square tests for differences in probabilities were used to test the hypothesis that the probability of finding a bird in any given group size remained the same throughout the summer (see METHODS). Chi-Square tests were performed for the following species or species groups: Oldsquaw, Northern Pintail, Ruddy Turnstone, Baird's Sandpiper, Semipalmated Sandpiper, Lapland Longspur, Snow Bunting, loons, eiders, plovers, phalaropes, shorebirds, and gulls. In all cases the null hypothesis could be rejected at $p = 0.001$, indicating that for all species tested, probability of finding a bird in a particular flock size varied with season.

Some general patterns were revealed by the contributions to the Chi-Square statistic for the species tested. One pattern was a greater than expected number of birds in pairs in early June (courtship), a greater than expected number of single birds in late June to early July (incubation), and a greater proportion of birds in larger flocks in the latter half of the summer (fledging and migration). Birds conforming to this pattern were loons, shorebirds, phalaropes, and passerines (Figure 9). Gulls showed a similar pattern, except that a greater than expected number of gulls occurred in pairs in late June to early July, which corresponded to their incubation time.

Oldsquaw showed a slightly different pattern. Although there was a greater than expected number of Oldsquaw in pairs in early June (courtship), Oldsquaw were most often seen in groups of 10 or more birds throughout the summer, and increasingly greater numbers of Oldsquaw were observed in increasingly larger flocks as the season progressed (Figure 9). This pattern reflects the congregation of non-breeders and failed nesters along coastal shorelines.

Northern Pintails were most numerous along shorelines during their migration, and hence were observed primarily in group sizes of 3-50 birds (Figure 9). Eiders were most often seen in groups of 3-10 birds, except in late July to early August (midsummer eider molt migration) when the greatest number were seen in groups of 11-50 birds.

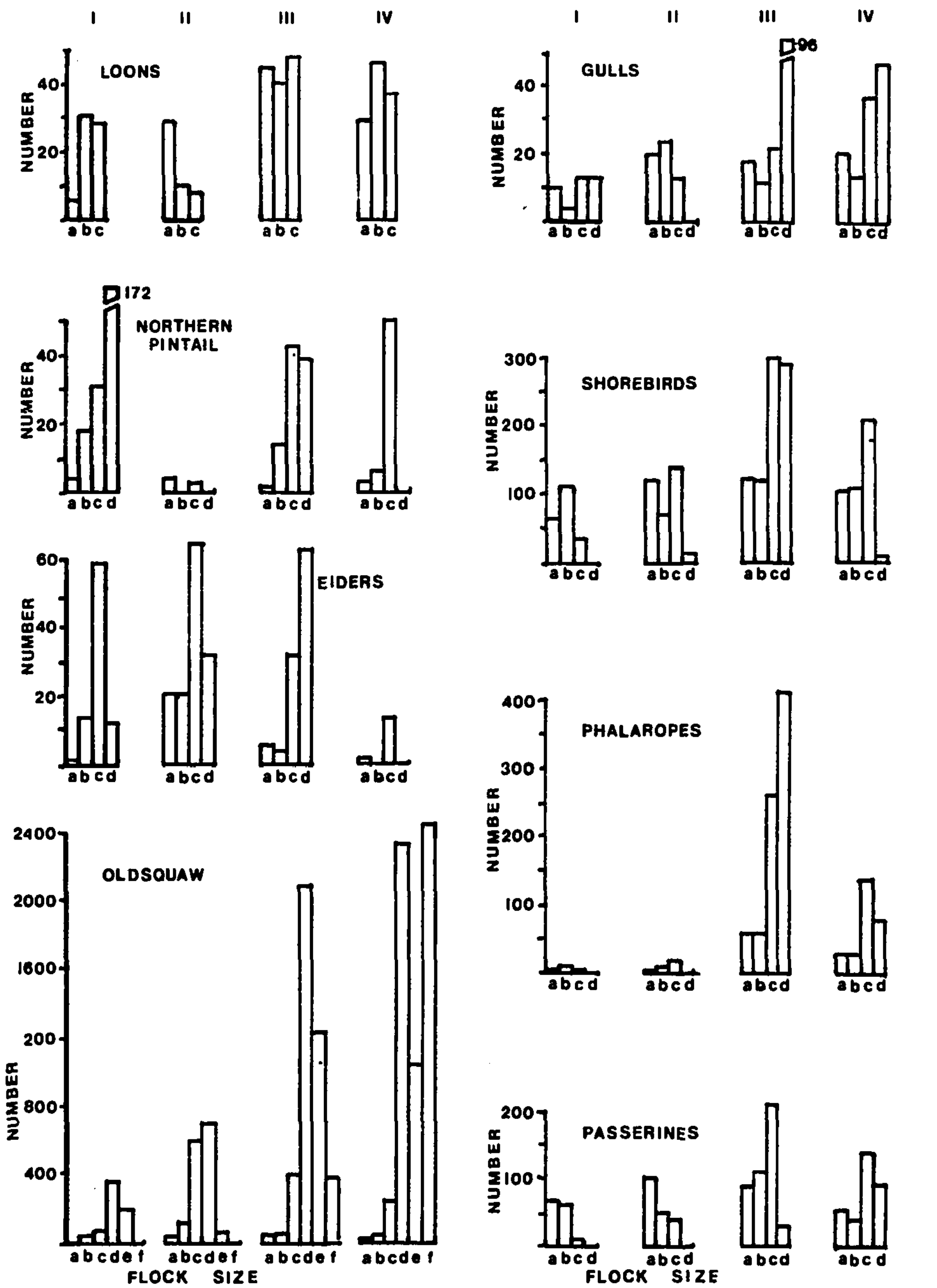


FIGURE 9. Seasonal change in numbers of birds in various flock sizes along shorelines at Canning River Delta, Alaska, 1980. (Flock size: a = 1 bird; b = 2 birds; c = 3-10 birds; d = 11-50 birds; e = 51-100 birds; f = over 100 birds. Time periods: I = 1-24 June; II = 28 June - 22 July; III = 24 July - 14 August; IV = 17 August - 6 September.)

## HABITAT INFLUENCE ON BIRD USE OF CANNING RIVER DELTA SHORELINES

### Identification and Description of Habitats

When studying relationships between organisms and their habitats, it is common practice for a researcher to define the habitats *a priori*, and then attempt to describe the difference in use of these defined habitats by the organisms in question. This approach is somewhat arbitrary, however, in that the variables used by the researcher to define habitats may not be factors that influence choice of habitat by the organism. The TWINSPAN ordination (see METHODS) was used to analyze Canning Delta bird census data in an attempt to distinguish differences in habitat from the birds' point of view. I made the assumption that units of shoreline which showed a similarity in the numbers and species composition of birds using them were perceived as similar habitat by the birds. Once these similar habitat units were defined by the birds' use, I attempted to describe the physical or biological parameters which made these habitats similar.

The TWINSPAN analysis yielded a clustering and ordination of 54 shoreline habitat units (each 500 m long) according to the similarity or dissimilarity of bird species and numbers observed in the units. The results of this analysis, with preferential bird species for each level of division, are shown in Table 3. Six shoreline habitats were identified. Table 4 shows relative densities of each bird species in each habitat. The approximate distribution at Canning Delta of the 500 m habitat units defined by the TWINSPAN analysis are shown in Figure 10.

The first division in the TWINSPAN analysis clearly separated 26 MAINLAND SHORELINE habitat units from 28 BARRIER ISLAND/GRAVEL BEACH habitat units. Three shorebird (Baird's Sandpiper, Semipalmated Sandpiper, Lesser Golden-Plover) and two passerine (Lapland Longspur, Snow Bunting) species showed a clear preference for MAINLAND habitat (Table 3), while BARRIER ISLAND habitat was associated with high densities of Oldsquaw, phalaropes, and Sanderling. (These species occurred in all habitats [Table 4], but high densities were characteristic of the

TABLE 3. Coastal shoreline habitats identified at Canning River Delta, Alaska, by TWINSPAN analysis of 1980 bird census data, with preferential bird species listed for each division. Numbers in parentheses are numbers of 500 m shoreline units in each division.

---

MAINLAND SHORELINE (26)
- Lapland Longspur
- Baird's Sandpiper
- Semipalmated Sandpiper
- Snow Bunting
- Lesser Golden-Plover

SALINE MEADOW/LITTORAL FLATS (6)
- Northern Pintail (high density)
- Canada Goose
- Ruddy Turnstone (high density)
- Pectoral Sandpiper (high density)
- Buff-breasted Sandpiper

BLUFF/DUNE/LOW LAGOON SHORE (20)
- Snow Bunting (high density)
- Rock Ptarmigan

DUNE/LOW LAGOON SHORE (9)
- King Eider

BLUFF (11)
- Rock Ptarmigan
- Glaucous Gull
- Snow Bunting (high density)
- Baird's Sandpiper
- Tundra Swan

BARRIER ISLAND/GRAVEL BEACH (28)
- Oldsquaw (high density)
- Red and Red-necked phalaropes (high density)
- Sanderling (high density)

BARRIER ISLAND TIPS (9)
- Arctic Tern
- Common Eider
- Arctic Loon (high density)

BARRIER ISLAND NON-TIPS (19)
- (no outstanding preferential species)

DEEP WATER BARRIER ISLAND (16)
- Red-throated Loon
- Glaucous Gull

SHALLOW WATER BARRIER ISLAND (3)
- Dunlin
- Black-bellied Plover
- Lesser Golden-Plover
- Northern Pintail

TABLE 4. Relative densities of bird species in six coastal shoreline habitats identified from TWINSPAN analysis of 1980 shoreline censuses at Canning River Delta, Alaska. Numbers represent the following averages of numbers of birds seen per 500 m shoreline unit over the entire summer: 0 = no birds; * = less than 1 bird; 2 = 2-4 birds; 3 = 5-9 birds; 4 = 10-19 birds; 5 = 20 or more birds.

| | Mainland | | | Barrier Island/Gravel Beach | | |
|---|---|---|---|---|---|---|
| Species | Saline Meadow | Dunes | Bluff | Shallow Water | Deep Water | Tips |
| (number of 500 m units) | (8) | (11) | (7) | (3) | (16) | (9) |
| Rock Ptarmigan | 0 | 1 | 2 | 0 | 1 | 0 |
| Long-billed Dowitcher | 0 | * | * | 0 | 0 | 0 |
| Snowy Owl | 0 | * | * | 0 | 0 | 0 |
| Short-eared Owl | 0 | 0 | * | 0 | 0 | 0 |
| _Empidonax_ sp. | 0 | 0 | * | 0 | 0 | 0 |
| Common/Hoary Redpoll | 0 | 0 | * | 0 | 0 | 0 |
| White-throated Sparrow | 0 | 0 | * | 0 | 0 | 0 |
| Gyrfalcon | 0 | * | 0 | 0 | 0 | 0 |
| Bar-tailed Godwit | 0 | * | 0 | 0 | 0 | 0 |
| Snow Bunting | 2 | 2 | 4 | 1 | * | 0 |
| Semipalmated Sandpiper | 4 | 3 | 3 | 1 | 1 | * |
| Baird's Sandpiper | 4 | 3 | 3 | * | * | 0 |
| Lapland Longspur | 5 | 4 | 5 | * | * | 0 |
| Lesser Golden-Plover | 1 | 2 | 2 | 2 | 0 | 0 |
| Stilt Sandpiper | * | 1 | * | 0 | 0 | 0 |
| Western Sandpiper | 1 | * | * | 0 | 0 | 0 |
| Greater White-fronted Goose | 2 | 0 | * | 0 | 0 | 0 |
| Mallard | * | 0 | 0 | 0 | 0 | 0 |
| Gadwall | * | 0 | 0 | 0 | 0 | 0 |
| American Wigeon | 1 | 0 | 0 | 0 | 0 | 0 |
| Tundra Swan | 2 | 0 | 1 | 0 | 0 | 0 |
| Brant | 3 | 2 | 0 | * | 0 | * |
| Pectoral Sandpiper | 2 | 1 | 1 | 1 | 0 | * |
| Buff-breasted Sandpiper | 2 | * | 1 | 0 | 0 | 0 |
| Canada Goose | 3 | 0 | 1 | 1 | 0 | 0 |

TABLE 4. (contd.)

| Species | Mainland: Saline Meadow | Dunes | Bluff | Barrier Island/Gravel Beach: Shallow Water | Deep Water | Tips |
|---|---|---|---|---|---|---|
| Northern Pintail | 5 | 2 | 1 | 2 | 1 | * |
| Ruddy Turnstone | 4 | 2 | 1 | 1 | 1 | * |
| White-rumped Sandpiper | 1 | 1 | * | * | * | 0 |
| Black-bellied Plover | 1 | 1 | 1 | 2 | * | 0 |
| King Eider | 1 | 2 | 1 | 1 | * | 2 |
| Dunlin | 3 | 1 | 1 | 3 | * | 1 |
| Yellow-billed Loon | 0 | 0 | * | 0 | * | 0 |
| Red-breasted Merganser | 1 | 0 | * | 1 | 1 | 1 |
| Black-legged Kittiwake | 0 | 0 | 0 | 1 | * | 0 |
| Parasitic Jaeger | * | 0 | 0 | 0 | * | 0 |
| Red-throated Loon | 1 | 1 | 1 | 0 | 2 | 2 |
| Oldsquaw | 3 | 3 | 3 | 5 | 5 | 5 |
| Surf Scoter | 0 | 0 | * | 0 | * | 0 |
| Sanderling | 2 | 1 | 1 | 3 | 3 | 1 |
| Red/Red-necked Phalarope | 3 | 2 | 2 | 4 | 4 | 4 |
| Arctic Loon | 2 | 1 | 2 | 2 | 2 | 3 |
| Glaucous Gull | 1 | * | 2 | * | 1 | 2 |
| Sabine's Gull | * | * | * | 1 | * | 1 |
| Arctic Tern | 1 | * | * | 2 | 1 | 3 |
| Common Eider | 1 | * | * | 0 | 1 | 3 |
| Snow Goose | 0 | 0 | 0 | 0 | 0 | * |
| White-winged Scoter | 0 | 0 | 0 | 0 | 0 | * |
| Red Knot | 0 | 0 | 0 | 0 | * | * |
| Black Guillemot | 0 | 0 | 0 | 0 | * | 2 |

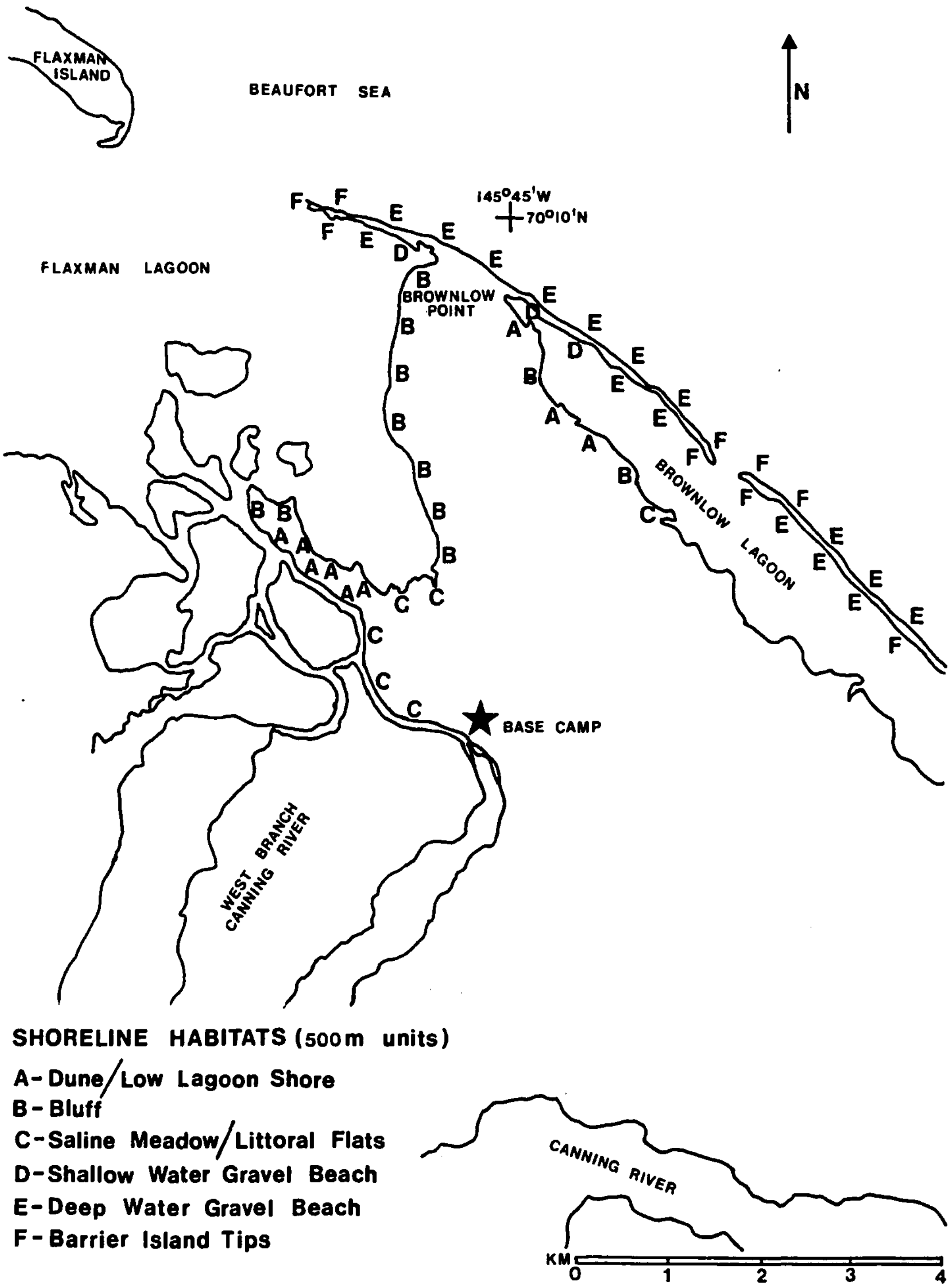


FIGURE 10. Distribution of six shoreline habitats identified by bird use at Canning River Delta, Alaska, 1980.

barrier islands.) MAINLAND SHORELINE habitat included lagoon, bay, and river shorelines backed by vegetated tundra, with or without silty or rocky beaches. BARRIER ISLAND/GRAVEL BEACH habitat consisted of low essentially unvegetated sand and gravel beaches. These beaches occurred as distinct barrier islands enclosing lagoons, but also occurred adjacent to mainland shorelines where these intersected barrier island spits, as at Brownlow Point (Figure 10).

The second division of the MAINLAND SHORELINE habitats separated 6 SALINE MEADOW/LITTORAL FLATS habitat units from 20 BLUFF/DUNE/LAGOON SHORE units. Bird species which showed a distinct preference for SALINE MEADOW/LITTORAL FLATS habitat were Northern Pintail, Canada Goose, Pectoral Sandpiper, Ruddy Turnstone, and Buff-breasted Sandpiper. All species of geese and dabbling ducks were found at highest densities in this habitat (Table 4), and Baird's Sandpiper, Semipalmated Sandpiper, and Lapland Longspur were also at high densities. SALINE MEADOW/LITTORAL FLATS shoreline habitat was characterized by low-lying flat silty substrate adjacent to shallow water, subject to periodic inundation by salt water, sparsely vegetated with <u>Carex</u> <u>subspathacea</u>, <u>Puccinellia</u> <u>phryganodes</u>, <u>Stellaria</u> <u>humifusa</u>, <u>Cochlearia</u> <u>officinalis</u>, and occasional clumps of other grass or sedge species.

BLUFF/DUNE/LAGOON SHORE habitat was distinguished by higher densities of Snow Bunting and Rock Ptarmigan than elsewhere. A further division of this habitat group separated 11 BLUFF shoreline habitat units from 9 DUNE/LOW LAGOON SHORE units. BLUFF habitat was distinguished by higher densities of Rock Ptarmigan, Glaucous Gull, Snow Bunting, Baird's Sandpiper, and Tundra Swan than the DUNE/LOW LAGOON SHORE habitat. The only species showing a clear preference for DUNE/LOW LAGOON SHORE habitat was King Eider. This species also showed a preference for barrier island tip habitat, but this preference was confined mainly to early spring, when some of the first open water appeared at barrier island tips. All bird species characteristic of MAINLAND SHORELINE habitat were found in DUNE/LOW LAGOON SHORE habitat, but most showed a greater preference for either SALINE MEADOW/LITTORAL FLATS habitat or BLUFF habitat.

The distinction between BLUFF habitat and DUNE/LOW LAGOON SHORE habitat was less clearly defined than for the preceding habitats. Most units included in the BLUFF category contained high steep bluffs (2-4 m high), dry tundra vegetation, and a narrow rocky or nonexistent beach. However, some units in this category had lower (1 m) banks edging wide silty mudflats. Units in the DUNE/LOW LAGOON SHORE category had low (1 m or less) banks and narrow or nonexistent beaches, although some units contained small silty inlets. Units in this category often had sandy soil, and vegetation ranged from dry tundra to moist tundra to sparse salt-influenced vegetation.

The second division of the BARRIER ISLAND/GRAVEL BEACH habitat separated 9 BARRIER ISLAND TIP habitat units from 19 BARRIER ISLAND NON-TIP units. The BARRIER ISLAND TIP habitat was distinguished by high densities of Arctic Tern and Common Eider; Arctic Loon also showed a preference for tips over non-tips. BARRIER ISLAND TIPS had slightly higher elevation and greater width than NON-TIPS due to build-up of accretionary spits, and were also characterized by adjacent flow of water between lagoon and ocean systems.

No species were outstanding in distinguishing BARRIER ISLAND NON-TIP habitat; these units contained all species characteristic of BARRIER ISLAND/GRAVEL BEACH habitat but none at exceptional densities. A further division of the BARRIER ISLAND NON-TIP habitat units separated 3 SHALLOW WATER BARRIER ISLAND habitat units from 16 DEEP WATER BARRIER ISALND units. The SHALLOW WATER units were located on the lagoon side of barrier island spits near their connection with the mainland; they were characterized by shallow water and silty substrate. Shallow water feeders, which were normally associated with MAINLAND SHORELINE habitat units (Dunlin, Black-bellied Plover, Lesser Golden-Plover, Northern Pintail) distinguished these barrier island units from the DEEP WATER BARRIER ISLAND units, which had higher densities of Red-throated Loon and Glaucous Gull than the SHALLOW WATER units.

Johnson and Richardson (1980) analyzed their Simpson Lagoon shoreline data by three transect types: seaward shorelines of barrier islands, lagoonward shorelines of barrier islands, and mainland shorelines. My TWINSPAN analysis of 1980 Canning Delta data confirmed "mainland vs. barrier island" as a major distinction in habitat, but did not distinguish "seaward vs. lagoonward" shores of barrier islands. However, although these shorelines could not be classified as distinct habitats based on the birds using them, there were differences in timing of use (see below).

Four shoreline habitats were identified by Connors et al. (1981) in studies at Barrow, Prudhoe Bay, and Harrison Bay. Habitat distinctions were based on a principal components analysis of six habitat variables and a principal coordinates analysis of presence/absence of bird species. The habitats identified were 1) gravel beaches (which would include all three barrier island habitats described for Canning Delta), 2) littoral flats and saltmarsh (which corresponds to the saline meadow habitat described for Canning Delta), 3) slough and small lagoon edges (which corresponds to the dune and low lagoon shore habitat described for Canning Delta), and 4) mainland shores (the bluff habitat described for Canning Delta appears to fit in this category).

Thus, the shoreline habitats I identified at Canning Delta by TWINSPAN analysis of bird use corresponded closely with those identified by Connors et al. for other Beaufort Sea shorelines. Connors et al. found, as I did, that "on the basis of species occurrence alone, the similarities between littoral flats and lagoon and slough edges are greater than between these habitat classes and gravel beaches" (Connors et al. 1981:43). My TWINSPAN analysis of Canning Delta habitats showed a clearer distinction between saline meadow/littoral flats habitat and lagoon shore habitat than did Connors et al.'s analysis, probably because the TWINSPAN analysis took species density into account, while Connors et al. based their analysis solely on presence/absence data. Most Canning Delta species that were found in saline meadow/littoral flats habitat were also observed in lagoon shore habitat, but in lower densities (Table 4). Thus, the main distinguishing feature of the saline meadow/littoral flats habitat was the much higher intensity of bird use. Migrating shorebirds and geese seemed to prefer this habitat for resting and feeding.

Importance of Barrier Island Tips and Gaps

The analysis by Connors et al. (1981) did not distinguish any subdivision of barrier island/gravel beach habitats in contrast to my TWINSPAN analysis of Canning Delta bird use. Again, the use of only presence/absence data might be the reason. At Canning Delta the use of barrier island tips by Arctic Terns and Common Eiders distinguished tips from non-tips. These two species were seen elsewhere on barrier islands, but were more numerous at the tips, due to an apparent preference for barrier island tips (especially western tips) as nesting sites. Hopkins and Hartz (1978) observed that the east-west direction of Beaufort long-shore ocean currents cause a build-up of sediments at the western tips of barrier islands and cause erosion of the eastern tips. The result is that western tips of barrier islands tend to migrate westwards and tend to have higher elevation and greater width than the rest of the island. The advantage of this higher elevation to birds was clearly demonstrated during a storm surge on 29 August 1980, when the entire barrier island of Brownlow Lagoon was wave-washed except for the western end, the area of the Arctic Tern colony and Common Eider nests.

In addition to use by nesting species, the tip area of barrier islands appeared to be important to other species, such as loons and Old-squaw, due to juxtaposition with water gaps between the barrier islands. Griffiths and Dillinger (1980) found that densities and biomass of invertebrate prey items (for fish and birds) varied widely during the open water season in Simpson Lagoon. They suggested that current-assisted movements of invertebrates into, out of, and within the lagoon may be important in their distribution. Thus, gaps in barrier islands appear to be important funnels of invertebrate prey, as strong tidal or wind-driven currents move water into and out of lagoons through these gaps. Campbell (1980:227) stated that "outflowing fresh water entrains nutrient-rich deep water, which causes mixing and an increased nutrient supply at the surface," suggesting that the mixing of waters near gaps between barrier islands could make these areas richer in nutrients and probably richer in invertebrate prey.

I applied Friedman tests to the Oldsquaw census data for the six barrier island transects at Canning Delta to test the hypothesis that birds showed a differential distribution around gaps between barrier islands (see METHODS). On all three outside (or oceanside) barrier island transects, as well as on the inside west spit transect, the Friedman tests could not disprove the null hypothesis, i.e., there was no significant difference in Oldsquaw distribution between 500 m subunits within these transects. Friedman tests for the inner east spit and inner barrier island transects significantly rejected the null hypothesis ($T2 \gg F$ at $p = 0.01$), however, indicating a non-random distribution of Oldsquaw along the inner side of the barrier islands enclosing Brownlow Lagoon. Examination of the results showed that higher numbers of Oldsquaw occurred within 1 km of the gap in the barrier island than elsewhere on these transects. In other words, Oldsquaw inside the barrier islands exhibited a preference for the gap, whereas those outside the barrier islands did not.

### Comparative Use of Inner and Outer Shores of Barrier Islands

Since the data set used for the TWINSPAN analysis was composed of totals of bird species seen over the entire summer, it could not show differences in habitat use due to timing. Seasonal differences in the use of outer (oceanside) and inner (lagoonside) shores of barrier islands were revealed, however, in data from individual censuses.

Distribution and numbers of Oldsquaw and phalaropes along the barrier islands of Brownlow Lagoon for the three censuses of the entire lagoon are shown in Figure 11. Oldsquaw numbers doubled between the first and second census, but then remained near the same level (about 1000 birds) for the third census. However their distribution shifted

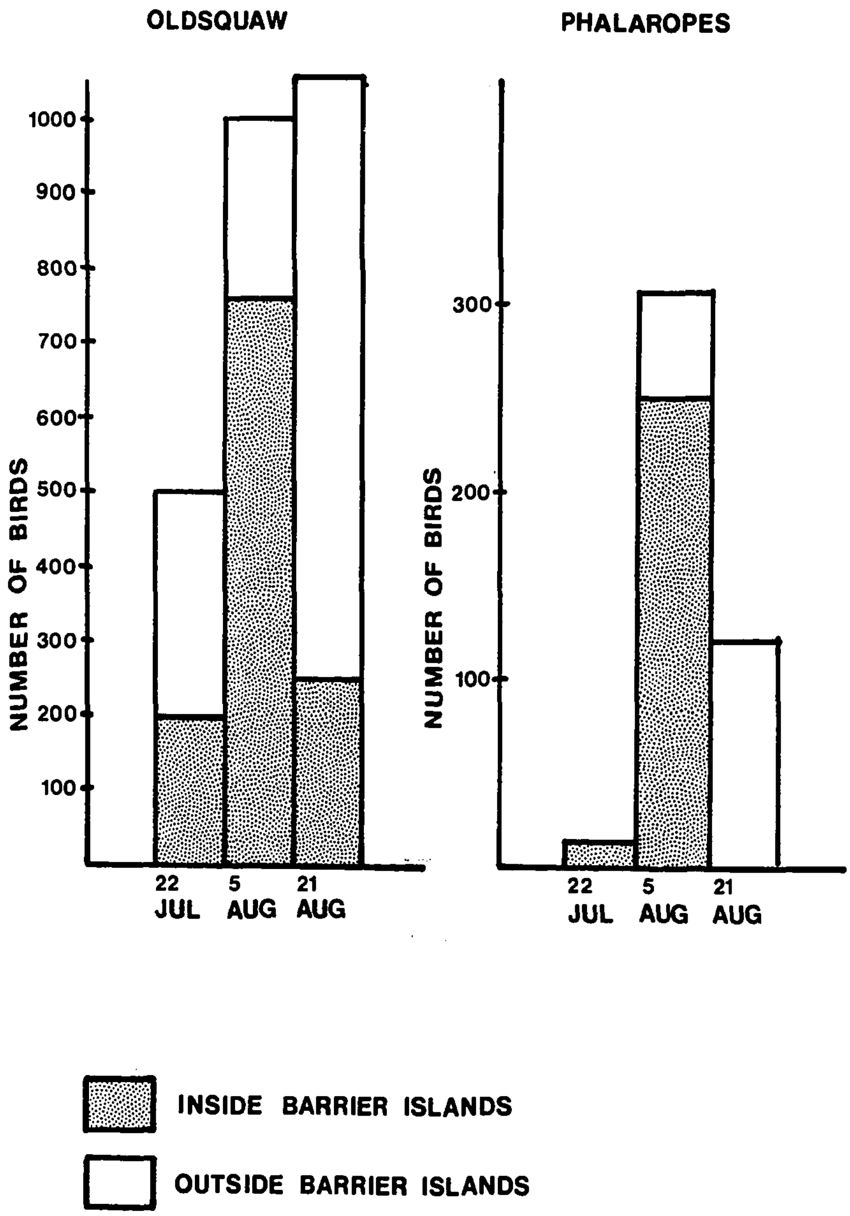


FIGURE 11. Oldsquaw and phalarope numbers from 1980 surveys of Brownlow Lagoon, Canning River Delta, Alaska.

from a more or less equal inside/outside ratio on 22 July, to a greater proportion inside the barrier islands on 5 August, during the peak of Oldsquaw wing molt. The onset of fall westward migration brought a greater proportion of Oldsquaw outside the barrier islands on the 21 August census, as flying flocks often stopped to rest outside the lagoon. The same pattern of Oldsquaw distribution relative to the barrier islands was demonstrated by the transect censuses (Figure 7).

Phalarope distribution followed a similar pattern: predominantly on the inner shore of the barrier islands on 5 August and 100% on the outer shores on 21 August. Both Connors and Risebrough (1978) and Johnson and Richardson (1980) reported correlations between wind direction and phalarope use of the leeward sides of barrier islands. They suggested a preference by phalaropes for oceanside beaches except on days of strong winds from offshore. The data from Brownlow Lagoon do not fit this pattern, as both 5 August and 21 August were relatively calm. Tidal stage was also similar for both censuses. The most likely explanation for the difference in phalarope distribution was a difference in food availability. Griffiths and Dillinger (1980) suggested that invertebrate food availability may be highly variable and unpredictable from place to place, season to season, and year to year in the Beaufort Sea barrier island-lagoon systems. Further studies would be necessary to clarify these relationships.

## EFFECTS OF WEATHER, TIDE, AND ICE COVER ON BIRD USE OF CANNING RIVER DELTA SHORELINES

Canning River Delta has an arctic coastal climate, similar to that recorded by the nearest U.S. Weather Service station, at Barter Island, 85 km to the west. The Beaufort Sea is generally frozen from October or November through June. During the summer months, when there are varying amounts of open water, the sea exerts a moderating influence on coastal climate, giving warmer autumns and cooler spring and summer temperatures than inland areas. At Barter Island the mean daily maxima (30 yr avg 1948-1978) were 3.4°C for June, 7.5°C for July, and 6.4°C for August. Heavy fog is characteristic of the coastal area in summer and is recorded on about half the days during June, July, and August at Barter Island (U.S. Dept. Commerce 1979). Wind is a constant element of arctic coastal weather. At Barter Island summer winds are predominantly east to east-northeast, with mean wind speeds of 17-18.5 km/hr (U.S. Dept. Commerce 1979). Strong winds also occur from the west, but north or south wind is uncommon. Annual precipitation at Barter Island is about 165 mm (30 yr avg 1948-1978), with about 70 mm falling from June through August (U.S. Dept. Commerce 1978).

At Canning Delta the summers of 1979 and 1980 differed markedly (Martin and Moitoret 1981). Above-average temperatures in May 1979 caused early melt-off of snow, and July 1979 was the fourth warmest July in 30 years of records at Barter Island. In 1980 May was colder than average, snow-melt did not begin until 1 June, and July was the second coldest in 30 years of records at Barter Island. Weather records for 1980 also showed unusual wind conditions in late August, when predominantly westerly winds replaced the normal prevailing easterly winds. A westerly storm on 29-30 August 1980 brought winds peaking at 90 km/hr to Barter Island, and the resultant storm tides considerably altered the coastline at Canning Delta.

Due to the colder than normal temperatures in the summer of 1980, snow-melt and ice break-up were slower than usual. Open water appeared first in the river and near the gap of the barrier island. The West Branch Canning River was open by 8 June, but ice remained in Brownlow Lagoon until 28 June, and a major offshore lead did not appear until 1 July, when the bay was also ice-free. Icebergs remained visible within 1 km of shore throughout the summer until 30 August. Ice was forming on the river and bay edge by 9 September.

The presence of snow and ice was a dominant factor influencing bird use of shorelines at Canning Delta in spring 1980. During spring migration the West Branch Canning River was the only available open water, and it was used heavily for resting and feeding by migrating waterfowl (Brant, Northern Pintail, American Wigeon, King Eider). Likewise, the higher wind-swept bluffs and dunes along shorelines had the earliest snow melt-off, and thus provided the first available habitat for migrating tundra-nesting birds. In particular, the dunes area of the river transect received high use by a large variety of shorebirds in the spring, but these birds subsequently moved to other tundra areas for nesting as snow-melt proceeded.

Wind speed and direction may affect bird migration, as has been noted for Brant and Oldsquaw on the Beaufort Sea coast (Richardson 1978). Adverse wind conditions might force migrating birds to the ground for resting or feeding. For those species following coastal migration routes, adverse winds could thus influence the use of adjacent shoreline habitat. In fall 1980 at Canning Delta, abnormal westerly winds may have caused more frequent stops by migrating waterfowl and shorebirds. For example, strong west winds on 30 August brought an influx of about 2000 migrating Oldsquaw to the shelter of Brownlow Lagoon and the barrier islands. Migrating Brant, which usually flew low along the mainland shoreline during their westward fall migration, frequently stopped to rest and feed in the saline meadows and littoral flats of the lagoon and bay shores. Oldsquaw in Brownlow Lagoon were normally most common along the barrier island shoreline, but on days of strong westerly (offshore) winds, flocks were often found in the lee of the shoreline bluffs of the mainland shores of the lagoon. Wind also had indirect effects on bird use of shorelines. The west winds of 29-30 August 1980 caused waves in Brownlow Lagoon which deposited a layer of detritus along the inner shore of the barrier islands. On the following day Sanderlings were observed feeding heavily in this wave-deposited detritus, whereas they were otherwise seen more commonly on the outer shores of the barrier islands. The storm surge of 29-30 August 1980 totally washed over most of the barrier island of Brownlow Lagoon, submerged extensive areas of saline meadow shoreline, and deeply undercut the bluff transect shoreline. Strong winds sometimes caused water to back up in Brownlow Lagoon, such that water could be seen flowing out through the gap in the barrier island during an incoming tide.

Tide itself probably had no major effect on bird use of shoreline habitats at Canning Delta, because tidal fluctuations were minor compared to wind-caused fluctuations in water level. Tidal fluctuation at Canning Delta during summer 1980 did not exceed 0.3 m (lowest low tide, -0.05 m, highest high tide, +0.25 m [U.S. Dept. Commerce 1980]).

Weather factors in general could have numerous indirect effects on timing and magnitude of bird use of shoreline habitats at Canning Delta by influencing timing of migrations, nesting chronologies, and nesting success. The later snow-melt in 1980 caused later nest initiation by Lapland Longspurs compared to 1979 (Martin 1983). The unusually cold wet weather in July 1980 suppressed insect emergence and may have increased nestling mortality (Martin 1983).

The difference in timing and magnitude of phalarope migration along Canning Delta shorelines in 1980 compared to 1979 provided an example of the large variations that can occur in bird use of Beaufort Sea shorelines from one year to the next. The peak of fall phalarope migration occurred 2 weeks earlier in 1980 than in 1979, and peak numbers were only about 20% of those in 1979 (Figure 12). The huge peak of 18-20 August 1979 consisted entirely of fledged juveniles. Juveniles appeared in much lower numbers at Canning Delta in 1980, suggesting lower breeding success in that year.

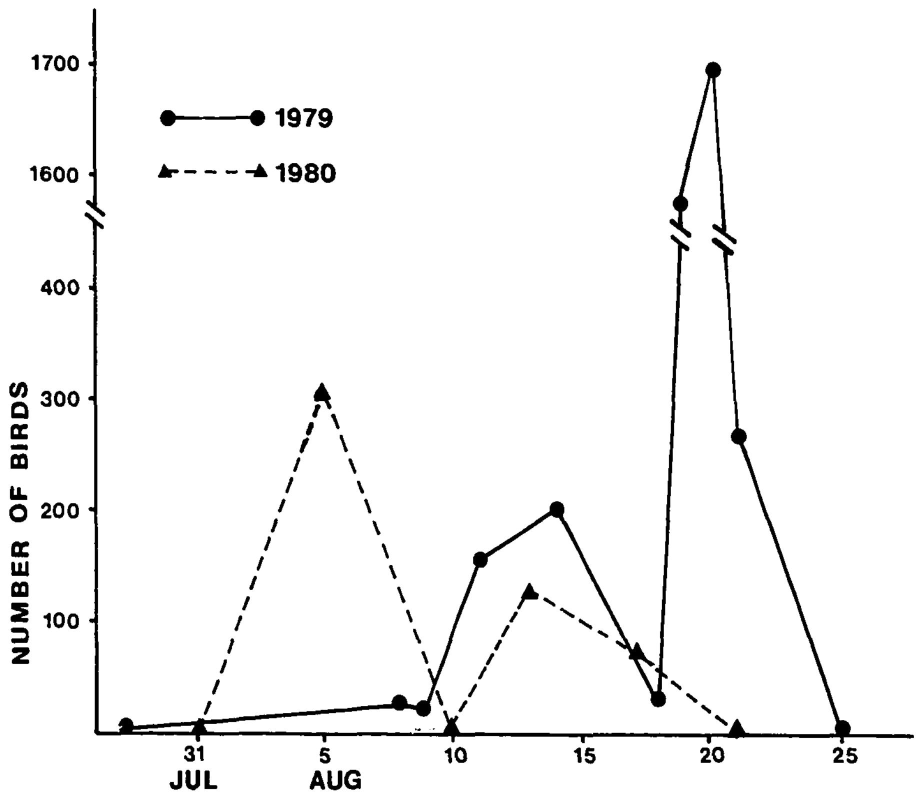


FIGURE 12. Number of phalaropes seen on spit west of Brownlow Point, Alaska, during fall migration 1979 and 1980. (1979 data from Martin and Moitoret 1981.)

Comparison of phalarope numbers along Simpson Lagoon shorelines in 1977 and 1978 (Johnson and Richardson 1980) also indicated variations in timing and magnitude of phalarope migration for those years (Figure 13). Comparisons between Simpson Lagoon and Canning Delta are difficult to interpret, since phalaropes on Simpson Lagoon shorelines were predominantly Red phalaropes, while those on Canning Delta shorelines were mostly Red-necked Phalaropes. However, these examples serve to illustrate the variations in timing and abundance of bird use of Beaufort Sea shorelines that can occur between years, and they emphasize the need for basing management decisions on multi-year studies.

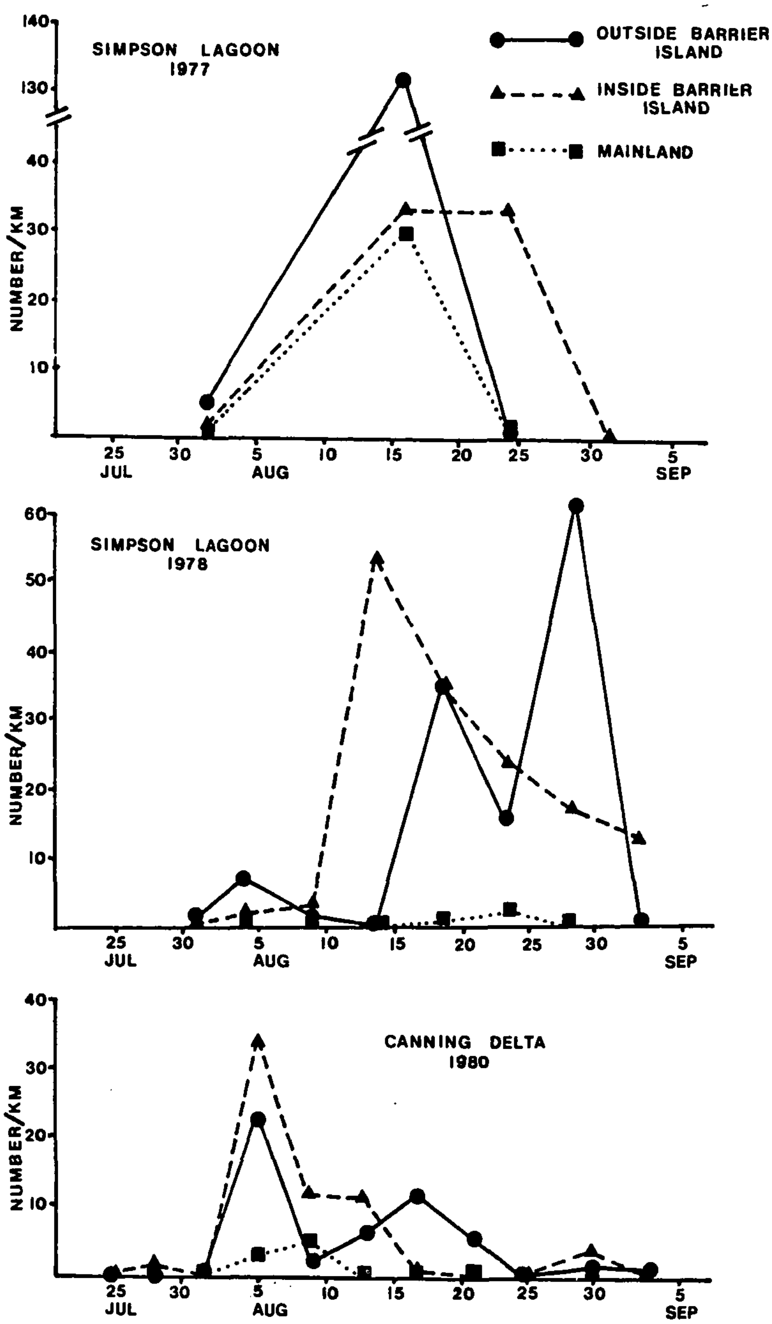


FIGURE 13. Number of phalaropes per kilometer on Simpson Lagoon and Canning River Delta shorelines, 1977, 1978, and 1980. (Simpson Lagoon data from Johnson and Richardson 1980.)

## HOW BIRDS USE CANNING RIVER DELTA SHORELINES

Birds use Beaufort Sea shoreline habitats in numerous ways. Because the coastline provides a natural corridor for migration, many migrants use shoreline habitats for resting, feeding, and staging. The coastline is less important as a migration corridor during spring migration than fall, because ice cover in spring makes it indistinguishable from land (Richardson and Johnson 1981). The extensive lagoon system along the Beaufort Sea coastline provides protected habitat for molting waterfowl, particularly Oldsquaw. Locally, nesting birds make use of the various rich food supplies in shoreline areas throughout their nesting seasons. These birds may nest along the shorelines, or they may nest further inland and fly to shoreline areas to feed.

At Canning Delta, ten bird species used coastal shoreline habitats for nesting: Tundra Swan, Northern Pintail, Oldsquaw, Common Eider, Ruddy Turnstone, Baird's Sandpiper, Glaucous Gull, Arctic Tern, Black Guillemot, and Snow Bunting. Of these ten species, only Common Eider and Black Guillemot were exclusive shoreline nesters, both choosing nest sites only on the barrier islands. Divoky (1978) found Common Eiders the most abundant and widespread species breeding on barrier islands in the Beaufort and Chukchi seas. Common Eiders were the most abundant shoreline breeders at Canning Delta, also, where we found 11 nests in 1980. The Black Guillemot was rare at Canning Delta; the single nest was located under a partially buried rusted oil drum on the barrier island of Brownlow Lagoon. Black Guillemots nesting in empty oil drums have been reported at other Beaufort Sea sites (MacLean and Verbeek 1968; Divoky 1978).

Tundra Swans, Northern Pintails, Oldsquaw, Glaucous Gulls, and Arctic Terns nested along coastal shorelines at Canning Delta, as well as at inland sites on tundra lakes. The driftwood piles, old buildings, and empty oil drums along shorelines provided the only suitable nest sites for Snow Buntings.

Baird's Sandpipers and Ruddy Turnstones most commonly used coastal shoreline nest sites at Canning Delta, although they may also use lake bluff or river shore habitat at inland sites. The favored nesting habitat for Ruddy Turnstones at Canning Delta was dry, flat, relatively unvegetated river floodplain or bluff top (50-90% bare ground within 1 m diameter of nest), while Baird's Sandpipers preferred more thickly vegetated bluff sites (only 1-30% bare ground within 1 m diameter of nest). These differences were reflected in their nest defense behaviors. Turnstones were visible, vocal, and aggressive in nest defense, while Baird's Sandpipers relied more on camouflage and concealment.

By far the most popular site for shoreline nesters at Canning Delta was the western tip of the barrier island enclosing Brownlow Lagoon, apparently because of its elevated position and proximity to a water gap (see above). Within 500 m of the gap, there was a colony of at least eight Arctic Tern nests, three Common Eider nests, two Oldsquaw nests, and one Black Guillemot nest. Other researchers have suggested that birds nesting on barrier islands tend to choose nest sites adjacent to Arctic Tern colonies because of the protection from avian predators afforded by the terns (Divoky 1978).

Two main factors were identified by Divoky (1978) as determining the importance of an island to breeding birds: 1) degree of isolation from terrestrial predators (arctic fox), and 2) amount and quality of cover. He found islands near river mouths most important, because the earlier ice melt resulted in isolation from the mainland in spring. In this regard, the islands at Canning Delta were favored by the influence of the Canning River; however, their geographic configuration did not give them much isolation. The nests at the western tip of the west spit were isolated only at high tide, and fox tracks were observed in this area. The nests at the western tip of the barrier island enclosing Brownlow Lagoon were isolated by a 100 m wide gap. However, both sites lacked cover, as there was no vegetation and little driftwood. Hence, the barrier islands near Brownlow Point were probably not particularly valuable to nesting birds. Ruth Island (Figure 3), a small island off the mouth of the West Branch Canning River, appeared to provide a more favorable site both in isolation and cover. It was located at least 1 km from the mainland and had sandy shorelines backed by high vegetated dunes. Only two censuses of this island were possible, but it appeared to have harbored at least one successful Common Eider nest, two successful Canada Goose nests, and one successful Glaucous Gull nest.

No islands at Canning Delta supported colonies the size of other Beaufort sites reported by Schamel (1977) and Divoky (1978), e.g., Cross Island (139 Common Eider nests) and Cooper Island (58 Arctic Tern nests). Shorelines at Canning Delta appeared to be relatively unimportant to breeding birds, although they were important to feeding and migrating shorebirds and waterfowl.

Birds also used Canning Delta shorelines for resting. The barrier islands were primarily used as resting places by gulls, terns, and waterfowl. Groups of Oldsquaw rested on the barrier islands or in the water adjacent to them at various times throughout the summer, and flocks of other ducks (King Eider, Northern Pintail, Red-breasted Merganser) and geese occasionally rested on or near the barrier islands during migration. A number of non-nesting female Common Eiders frequently rested on the barrier islands in the vicinity of the incubating females. Glaucous Gulls rested on both mainland and barrier island shorelines throughout the summer. Sabine's Gulls did not nest on the barrier islands at Canning Delta, but adults with their fledged young fed and rested on the barrier islands near the Arctic Tern colony in mid- to late August. Resident Arctic Terns were last observed on the barrier islands at Canning Delta on 17 August 1980, but 86 migrating Arctic Terns were observed resting on the barrier island on 1 September 1980.

Mainland shorelines were most frequently used for resting by Snow Buntings and Lapland Longspurs, which found shelter from the wind in the lee of shoreline bluffs and gullies. Brant and other geese used saline meadow areas for resting and feeding during their fall migration. Shorebirds were seen feeding more often than they were seen resting on shorelines, and probably preferred to rest under the protection of the vegetative cover of the tundra rather than in exposed shoreline areas. In the spring, Lapland Longspurs, Snow Buntings, Semipalmated, Baird's, and Buff-breasted sandpipers, and Rock Ptarmigan were all observed using shorelines for courtship display, but this activity was not limited to shorelines. Other bird activities observed on shorelines, but not limited to shorelines, included distraction displays, singing, calling, chasing, being chased, bathing, and preening.

By far the dominant use of Canning Delta shorelines by birds was for feeding. Food available to birds in shoreline areas includes fish (used by gulls, terns, mergansers, loons), various marine invertebrates (used by Oldsquaw, phalaropes, shorebirds), insect larvae (used by shorebirds and passerines), saltmarsh vegetation (used by geese) and seeds (used by passerines). In Simpson Lagoon, Oldsquaw fed principally on mysids, amphipods, and bivalves; phalaropes ate mainly copepods, amphipods, and mysids; and gulls preferred isopods, amphipods, and small fish (Johnson and Richardson 1980). At Barrow, there was a broad overlap in the diets of various shorebirds in shoreline habitats, and the main differences in diet corresponded to differences in habitat use (Connors and Risebrough 1981:63):

> Shorebirds foraging on littoral flats, in saltmarshes and along the shores of small lagoons and sloughs foraged principally on chironomid larvae in the substrate but in several areas small oligochaetes were also taken. Early in the post-breeding season (late July) adult chironomids are present and are taken by many species. Along gravel beaches on marine shores most species foraged on a wide variety of marine zooplankton and amphipods associated with the substrate or under the surface of the ice. The actual species taken varied widely over time and place both within a season and between seasons, but the differences in prey between species at one time and place were relatively slight.

Thus, although on Canning Delta shorelines some shorebirds fed at the water's edge and some fed in shallow water, and phalaropes fed in the water column near the water's edge, it is likely that they were all feeding on similar invertebrate prey. Their diets may also have overlapped with that of Oldsquaw, which dove for their food in deeper water. Such overlap in diet might have accounted for the correlations in phalarope and Oldsquaw numbers inside and outside barrier islands.

## SUMMARY AND CONCLUSIONS

Canning Delta shorelines were used by 51 species of birds in the summer of 1980, of which 8 were abundant, another 14 fairly common, and 29 uncommon or sporadic in shoreline use. Bird use of shoreline areas began with the arrival of the first migrants in late May, but there was a dramatic increase in use of shoreline areas by birds in late July and continuing through early September. This increase in bird numbers was accompanied by an increase in flock size, and it corresponded to the termination of nesting for most species and a general movement to coastal areas for feeding and staging prior to migration. It also corresponded to the molt period for Oldsquaw, which sought the protection of coastal lagoon systems.

Six coastal shoreline habitats were distinguished at Canning Delta, based on species and intensity of use by birds:

SALINE MEADOW/LITTORAL FLATS received the highest use by migrant shorebirds, geese, and dabbling ducks.

MAINLAND BLUFF received the highest use by Rock Ptarmigan, Snow Bunting, and Glaucous Gull.

DUNE/LOW LAGOON SHORE was intermediate in use between the first two habitats.

All three mainland shoreline habitats received high use by Semipalmated Sandpiper, Baird's Sandpiper, and Lapland Longspur.

BARRIER ISLAND TIPS received the highest use by Arctic Tern, Common Eider, and Arctic Loon.

SHALLOW WATER BARRIER ISLAND/GRAVEL BEACH was used by shallow water feeders associated with the mainland, such as Dunlin and Black-bellied Plover.

DEEP WATER BARRIER ISLAND/GRAVEL BEACH received higher use by Red-throated Loon and Glaucous Gull than shallow water barrier island/gravel beach.

All three barrier island habitats received high use by Oldsquaw, Sanderling, and phalaropes.

Ice and snow cover concentrated birds at river mouths and on exposed dunes or bluffs in the early spring, as these areas provided the first open water and open ground for resting and feeding. Tide was probably not a significant factor in bird use of coastal shorelines at Canning Delta, because tidal fluctuations were small and their effects were generally outweighed by the effects of wind-caused storm surges that could drastically modify shoreline habitats. Adverse winds appeared to cause migrating birds to seek rest, food, and shelter on shorelines. Weather factors may have had indirect effects on bird use of shoreline habitats through influence on nesting chronology, nesting success, availability of food, and timing of migration.

Ten species of birds used the shorelines for nesting, but the importance to nesting birds was low compared to other Beaufort Sea sites. Shorelines at Canning Delta were more important to feeding and migrating shorebirds and waterfowl.

The implications of these findings in terms of management concerns are as follows: The timing of any exploratory or developmental activity along Beaufort shorelines would have the least impact on birds if conducted during the winter months, and the greatest impact if conducted in late summer (mid-July to mid-September). The most sensitive locations in terms of impacts on birds are barrier islands (especially tips and gaps between them), saline meadows and littoral flats, and river mouths. The least sensitive areas are the mainland shorelines with steep bluffs edged by a narrow beach or no beach.

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APPENDIX 1. Number of birds per kilometer on each transect for each shoreline census at Canning River Delta, Alaska, 1980. (* = no data)

| Census Dates | Birds | Transects: outer west spit | inner west spit | outer east spit | inner east spit | outer bar. isl. | inner bar. isl. | lagoon | bluff | bay | river | Mean for all transects |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (length of transect in km) | | (2.2) | (1.8) | (2.5) | (2.5) | (2.5) | (2.5) | (3.2) | (2.6) | (4.1) | (3.6) | (27.5) |
| 5/29-6/07 | loons | 0 | 0 | 0 | 0 | * | * | 0 | * | * | 0.7 | 0.6 |
| | Oldsquaw | 0 | 0 | 0 | 0 | * | * | 11.9 | * | * | 12.2 | 4.7 |
| | other waterfowl | 0 | 0 | 0 | 0 | * | * | 9.4 | * | * | 32.5 | 7.8 |
| | shorebirds | 0 | 0 | 0 | 2.4 | * | * | 1.9 | * | * | 10.0 | 2.5 |
| | phalaropes | 0 | 0 | 0 | 0 | * | * | 0 | * | * | 0 | 0 |
| | passerines | 0 | 0 | 2.0 | 0 | * | * | 2.5 | * | * | 2.4 | 1.3 |
| | other birds | 0 | 0 | 0 | 0 | * | * | 0.9 | * | * | 0.8 | 0.3 |
| 6/08-6/10 | loons | * | * | 0 | 0 | * | * | 0.6 | 0 | * | 0 | 0.1 |
| | Oldsquaw | * | * | 0 | 36.0 | * | * | 0 | 0 | * | 4.0 | 7.2 |
| | other waterfowl | * | * | 0 | 3.6 | * | * | 7.2 | 0.7 | * | 16.9 | 6.5 |
| | shorebirds | * | * | 0 | 0 | * | * | 1.6 | 1.1 | * | 2.3 | 1.1 |
| | phalaropes | * | * | 0 | 0 | * | * | 0 | 0 | * | 1.7 | 0.4 |
| | passerines | * | * | 0 | 0 | * | * | 1.6 | 4.8 | * | 0.6 | 1.4 |
| | other birds | * | * | 0 | 4.4 | * | * | 0.6 | 0.4 | * | 0.3 | 1.0 |
| 6/12-6/14 | loons | 0 | 0 | 0 | 1.2 | * | * | 0 | 0 | 0.2 | 3.3 | 0.7 |
| | Oldsquaw | 3.6 | 0 | 0 | 35.6 | * | * | 0.6 | 0 | 0.9 | 1.4 | 4.7 |
| | other waterfowl | 0 | 0 | 0 | 2.4 | * | * | 3.8 | 2.2 | 1.0 | 2.0 | 2.2 |
| | shorebirds | 0.4 | 0 | 0 | 1.6 | * | * | 4.1 | 2.2 | 2.1 | 2.8 | 1.9 |
| | phalaropes | 0 | 0 | 0 | 0.4 | * | * | 0.3 | 0 | 0 | 0 | 0.1 |
| | passerines | 0.9 | 0 | 0 | 2.0 | * | * | 2.8 | 4.8 | 0.9 | 0.6 | 1.4 |
| | other birds | 0 | 3.3 | 0 | 0.4 | * | * | 0.6 | 0.7 | 0 | 0 | 0.7 |

APPENDIX 1. (contd.)

| Census Dates | Birds | Transects outer west spit | inner west spit | outer east spit | inner east spit | outer bar. isl. | inner bar. isl. | lagoon | bluff | bay | river | Mean for all transects |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/17 | loons | 0 | 1.1 | 0 | 2.4 | * | * | 0 | 0 | 0.9 | 0.3 | 0.6 |
| | Oldsquaw | 22.3 | 0 | 12.0 | 21.2 | * | * | 1.3 | 0 | 0.9 | 0.8 | 6.3 |
| | other waterfowl | 3.6 | 1.1 | 0.4 | 3.2 | * | * | 4.1 | 0 | 0.5 | 0 | 2.1 |
| | shorebirds | 0 | 0.6 | 0 | 0 | * | * | 0.9 | 2.2 | 3.8 | 2.5 | 1.5 |
| | phalaropes | 0 | 0 | 0 | 0 | * | * | 0 | 0 | 0.5 | 0 | 0.1 |
| | passerines | 0.4 | 0 | 0 | 0 | * | * | 1.9 | 3.3 | 3.1 | 0.8 | 1.4 |
| | other birds | 0.4 | 3.3 | 0 | 0.8 | * | * | 0 | 1.1 | 1.4 | 3.6 | 1.4 |
| 6/21 | loons | 0 | 2.8 | 2.4 | 0.8 | * | * | 0 | 0 | 0 | 0.8 | 0.7 |
| | Oldsquaw | 0 | 5.0 | 28.8 | 18.4 | * | * | 1.6 | 0.4 | 0.9 | 0.6 | 6.1 |
| | other waterfowl | 0 | 1.7 | 2.4 | 6.0 | * | * | 4.4 | 0 | 0.5 | 0.3 | 1.8 |
| | shorebirds | 0 | 0 | 0.4 | 0 | * | * | 3.5 | 3.8 | 1.4 | 2.2 | 1.6 |
| | phalaropes | 0 | 0 | 0 | 0.8 | * | * | 0.3 | 0.4 | 0 | 0 | 0.2 |
| | passerines | 0.4 | 0 | 0.4 | 0 | * | * | 1.3 | 4.2 | 0.7 | 1.9 | 1.2 |
| | other birds | 0 | 6.7 | 0 | 0.4 | * | * | 0.3 | 2.3 | 0 | 0 | 0.9 |
| 6/24 | loons | 0.9 | 0 | 2.0 | 0.4 | * | * | 0 | 0 | 0 | 0 | 0.3 |
| | Oldsquaw | 0 | 0 | 4.0 | 2.8 | * | * | 8.4 | 1.1 | 0.5 | 0.6 | 2.3 |
| | other waterfowl | 0 | 3.9 | 2.0 | 1.2 | * | * | 3.4 | 0.4 | 3.4 | 0.3 | 1.9 |
| | shorebirds | 0 | 0 | 0 | 0 | * | * | 6.3 | 1.1 | 1.2 | 2.8 | 1.7 |
| | phalaropes | 0 | 0 | 0 | 0 | * | * | 1.6 | 0 | 0 | 0 | 0.2 |
| | passerines | 0 | 0 | 0 | 0 | * | * | 1.9 | 2.7 | 0.5 | 0.3 | 0.7 |
| | other birds | 0.4 | 0 | 0 | 2.0 | * | * | 0.6 | 0.8 | 1.0 | 0.3 | 0.7 |

APPENDIX 1. (contd.)

| Census Dates | Birds | Transects: outer west spit | inner west spit | outer east spit | inner east spit | outer bar. isl. | inner bar. isl. | lagoon | bluff | bay | river | Mean for all transects |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/28 | loons | 0.4 | 0 | 0 | 0 | * | * | 0.3 | 0 | 0.2 | 0 | 0.1 |
| | Oldsquaw | 69.5 | 0 | 5.6 | 16.4 | * | * | 17.8 | 1.1 | 1.2 | 0.6 | 12.3 |
| | other waterfowl | 10.9 | 1.1 | 0.8 | 0 | * | * | 0.9 | 0 | 0.7 | 0.3 | 1.5 |
| | shorebirds | 0 | 0 | 0 | 0 | * | * | 1.3 | 1.5 | 2.4 | 3.9 | 1.5 |
| | phalaropes | 0 | 0 | 0 | 0 | * | * | 0.3 | 0 | 0 | 0 | 0 |
| | passerines | 1.4 | 0 | 0 | 0.4 | * | * | 1.9 | 4.2 | 0.7 | 1.4 | 1.3 |
| | other birds | 1.4 | 1.1 | 6.0 | 0.4 | * | * | 0.6 | 1.5 | 0.5 | 0.8 | 1.4 |
| 7/01-7/03 | loons | 0.9 | 0 | 0.4 | 1.2 | * | * | 0 | 0 | 0 | 0 | 0.3 |
| | Oldsquaw | 0.9 | 0 | 1.2 | 26.0 | * | * | 0 | 0 | 0.5 | 0.6 | 3.4 |
| | other waterfowl | 13.6 | 3.3 | 1.2 | 3.2 | * | * | 4.4 | 0 | 2.2 | 0.6 | 3.1 |
| | shorebirds | 0 | 0 | 0 | 0.4 | * | * | 2.8 | 1.9 | 7.3 | 4.4 | 2.7 |
| | phalaropes | 0 | 0 | 0 | 0 | * | * | 0 | 0 | 0.7 | 0 | 0.1 |
| | passerines | 0.4 | 0 | 0 | 0 | * | * | 1.9 | 4.2 | 2.7 | 0 | 1.3 |
| | other birds | 0 | 1.1 | 0 | 2.0 | * | * | 0 | 0.8 | 0.5 | 0 | 0.5 |
| 7/06 | loons | 1.4 | 0 | 0 | 0.4 | * | * | 0 | 0 | 0 | 0 | 0.1 |
| | Oldsquaw | 42.9 | 0 | 10.0 | 11.2 | * | * | 0 | 1.9 | 1.2 | 0 | 5.7 |
| | other waterfowl | 0.7 | 5.6 | 0 | 1.2 | * | * | 1.6 | 6.1 | 2.2 | 0 | 2.0 |
| | shorebirds | 0 | 0 | 0 | 0 | * | * | 0.6 | 3.8 | 7.8 | 4.4 | 2.8 |
| | phalaropes | 0 | 0 | 0 | 0 | * | * | 0 | 0 | 2.9 | 0 | 0.5 |
| | passerines | 0 | 0 | 0 | 0 | * | * | 0.6 | 4.6 | 0.5 | 0.8 | 0.9 |
| | other birds | 3.6 | 2.2 | 0.8 | 0.8 | * | * | 0 | 1.5 | 0.5 | 0.6 | 0.9 |

APPENDIX 1. (contd.)

| Census Dates | Birds | Transects: outer west spit | inner west spit | outer east spit | inner east spit | outer bar. isl. | inner bar. isl. | lagoon | bluff | bay | river | Mean for all transects |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7/10-7/11 | loons | 0 | 0 | 0 | 0 | * | * | 0 | 0.4 | 0.2 | 0 | 0.1 |
| | Oldsquaw | 2.7 | 1.7 | 34.4 | 10.4 | * | * | 0 | 1.9 | 0.7 | 0 | 5.7 |
| | other waterfowl | 0 | 21.1 | 4.0 | 0 | * | * | 0.6 | 0 | 0.2 | 0.6 | 2.4 |
| | shorebirds | 0 | 0 | 0 | 0.4 | * | * | 0.3 | 0.8 | 7.6 | 14.7 | 4.0 |
| | phalaropes | 0 | 0 | 0 | 0 | * | * | 0 | 0 | 0.2 | 0 | 0 |
| | passerines | 0.4 | 0 | 0 | 0 | * | * | 0.6 | 2.3 | 3.7 | 3.6 | 1.6 |
| | other birds | 0 | 0.6 | 0 | 0.4 | * | * | 0.3 | 0 | 0.7 | 0.8 | 0.4 |
| 7/16-7/18 | loons | 2.3 | 0.6 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0.2 | 0 | 0.3 |
| | Oldsquaw | 24.1 | 0 | 40.0 | 22.0 | 6.8 | 12.0 | 0 | 0 | 0.5 | 0 | 9.4 |
| | other waterfowl | 5.9 | 0 | 2.0 | 0.8 | 1.2 | 5.6 | 0.3 | 0.4 | 0 | 0.6 | 1.5 |
| | shorebirds | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.8 | 6.1 | 3.9 | 1.5 |
| | phalaropes | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | passerines | 0.4 | 0 | 0 | 0 | 0 | 0 | 2.2 | 10.0 | 1.7 | 1.9 | 1.7 |
| | other birds | 1.4 | 1.1 | 0 | 0.8 | 2.0 | 1.6 | 0.3 | 2.7 | 0 | 1.7 | 1.1 |
| 7/20-7/22 | loons | 0 | 0 | 0.8 | 0 | 0.8 | 0.4 | 0 | 0 | 0 | 0 | 0.2 |
| | Oldsquaw | 35.4 | 0 | 56.4 | 11.2 | 24.4 | 26.0 | 0 | 0 | 0.2 | 0 | 13.6 |
| | other waterfowl | 2.7 | 0 | 0.8 | 0 | 3.6 | 0 | 0 | 0 | 0 | 3.3 | 1.1 |
| | shorebirds | 0 | 0 | 0 | 0 | 0.8 | 0 | 1.9 | 4.2 | 7.8 | 3.3 | 2.3 |
| | phalaropes | 0 | 0 | 0 | 0 | 0 | 2.4 | 0 | 0 | 0.2 | 0 | 0.2 |
| | passerines | 0 | 0 | 0 | 0 | 0 | 0 | 1.3 | 5.8 | 2.2 | 1.9 | 1.3 |
| | other birds | 0 | 0.6 | 0 | 0 | 2.4 | 0.4 | 0.3 | 4.2 | 0.2 | 0 | 0.7 |

APPENDIX 1. (contd.)

| Census Dates | Birds | Transects: outer west spit | inner west spit | outer east spit | inner east spit | outer bar. isl. | inner bar. isl. | lagoon | bluff | bay | river | Mean for all transects |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7/24-7/26 | loons | 0 | 0 | 0 | 2.0 | 1.6 | 0 | 1.3 | 2.7 | 0 | 0 | 0.8 |
| | Oldsquaw | 38.2 | 2.2 | 22.8 | 42.0 | 34.4 | 32.0 | 0.3 | 0 | 1.7 | 0 | 15.4 |
| | other waterfowl | 0.9 | 0 | 2.8 | 0 | 8.8 | 5.2 | 2.8 | 0 | 7.8 | 6.7 | 3.9 |
| | shorebirds | 0 | 0 | 0 | 0 | 0 | 0.4 | 2.8 | 1.1 | 13.2 | 26.4 | 5.9 |
| | phalaropes | 0 | 0 | 0 | 0 | 0.8 | 0 | 0.3 | 0 | 0 | 0 | 0.1 |
| | passerines | 0 | 0.6 | 0 | 0 | 0 | 0 | 4.7 | 5.0 | 14.1 | 6.9 | 4.1 |
| | other birds | 0.4 | 0 | 0 | 0 | 3.6 | 1.2 | 0 | 14.6 | 0 | 7.5 | 2.8 |
| 7/28 | loons | 0 | 0 | 1.6 | 0 | 1.2 | 0.4 | 0.9 | 1.9 | 0 | 1.4 | 0.8 |
| | Oldsquaw | 92.7 | 0 | 74.8 | 29.2 | 20.0 | 6.0 | 0 | 19.2 | 0 | 0 | 21.1 |
| | other waterfowl | 13.2 | 0 | 2.0 | 0 | 0 | 6.8 | 0.9 | 0 | 2.4 | 0.3 | 2.4 |
| | shorebirds | 0 | 1.1 | 0 | 2.8 | 0 | 0.8 | 2.2 | 5.8 | 57.8 | 2.2 | 10.1 |
| | phalaropes | 0 | 0 | 0 | 0.8 | 1.2 | 6.4 | 0 | 0 | 1.0 | 0 | 0.9 |
| | passerines | 0.4 | 0 | 0 | 0 | 0 | 0 | 4.7 | 6.9 | 7.6 | 5.3 | 3.0 |
| | other birds | 0 | 0.6 | 0.4 | 0 | 3.6 | 0.4 | 0 | 0 | 0 | 0 | 0.4 |
| 8/01-8/02 | loons | 0 | 0 | 2.4 | 1.2 | 2.4 | 1.6 | 1.6 | 0 | 0.5 | 0 | 0.9 |
| | Oldsquaw | 15.4 | 0 | 66.0 | 38.4 | 38.4 | 53.6 | 0 | 0 | 0 | 0 | 19.1 |
| | other waterfowl | 0 | 0 | 0 | 0 | 0 | 1.2 | 0 | 0 | 0.7 | 0 | 0.2 |
| | shorebirds | 0 | 0 | 0 | 4.0 | 2.0 | 1.2 | 0.6 | 3.8 | 46.3 | 3.3 | 8.5 |
| | phalaropes | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.0 | 0 | 0.1 |
| | passerines | 0 | 0 | 0 | 0 | 0 | 0 | 1.3 | 3.1 | 10.2 | 4.4 | 2.5 |
| | other birds | 0 | 0 | 0 | 0 | 9.2 | 10.8 | 0.3 | 7.3 | 0.2 | 0 | 2.6 |

APPENDIX 1. (contd.)

| Census Dates | Birds | Transects: outer west spit | inner west spit | outer east spit | inner east spit | outer bar. isl. | inner bar. isl. | lagoon | bluff | bay | river | Mean for all transects |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8/05-8/06 | loons | 1.8 | 0 | 1.6 | 1.6 | 0.8 | 2.4 | 1.6 | 0 | 0.2 | 0 | 0.9 |
| | Oldsquaw | 36.4 | 26.1 | 27.2 | 198.8 | 76.0 | 48.4 | 60.0 | 1.9 | 0 | 0 | 43.7 |
| | other waterfowl | 0 | 1.1 | 0 | 0.8 | 0.4 | 0 | 3.1 | 0 | 1.0 | 0 | 0.7 |
| | shorebirds | 7.7 | 0 | 0 | 0.4 | 0.4 | 0.4 | 3.8 | 2.3 | 10.2 | 4.7 | 3.7 |
| | phalaropes | 75.0 | 2.2 | 0 | 78.4 | 2.8 | 16.4 | 8.4 | 1.9 | 0.7 | 0 | 16.1 |
| | passerines | 0 | 0 | 0 | 0 | 0 | 0 | 1.6 | 3.5 | 2.4 | 2.8 | 1.2 |
| | other birds | 0 | 0 | 0 | 0.4 | 2.0 | 1.6 | 0.9 | 0 | 0 | 0 | 0.5 |
| 8/09-8/11 | loons | 0 | 0 | 0 | 2.8 | 1.2 | 2.0 | 0.3 | 0.8 | 0.2 | 0 | 0.7 |
| | Oldsquaw | 15.9 | 0 | 28.8 | 52.8 | 14.4 | 49.6 | 6.6 | 39.6 | 0 | 0 | 19.0 |
| | other waterfowl | 0 | 0 | 0 | 1.2 | 0 | 0 | 0 | 0 | 2.4 | 0 | 0.5 |
| | shorebirds | 0 | 0 | 1.2 | 1.6 | 3.6 | 3.2 | 13.8 | 1.1 | 7.6 | 6.1 | 4.5 |
| | phalaropes | 0 | 0 | 4.8 | 27.2 | 0 | 6.0 | 18.1 | 0 | 0.7 | 0.6 | 5.7 |
| | passerines | 0 | 0 | 0 | 0 | 0 | 0 | 2.2 | 8.8 | 3.7 | 3.3 | 2.1 |
| | other birds | 0.9 | 2.2 | 0 | 0 | 7.6 | 2.4 | 0 | 5.8 | 0 | 0.8 | 1.7 |
| 8/13-8/14 | loons | 0.4 | 0 | 0.8 | 0 | 1.6 | 1.2 | 0.6 | 1.1 | 0 | 0.3 | 0.6 |
| | Oldsquaw | 65.4 | 8.9 | 52.4 | 33.6 | 125.2 | 10.0 | 0 | 0 | 0 | 0 | 25.9 |
| | other waterfowl | 0 | 0 | 0 | 0 | 0 | 0 | 0.6 | 0.4 | 1.0 | 1.7 | 0.5 |
| | shorebirds | 0 | 3.3 | 0.4 | 0 | 0 | 2.4 | 1.6 | 1.5 | 21.5 | 3.6 | 4.5 |
| | phalaropes | 2.7 | 30.6 | 7.2 | 0 | 8.8 | 9.2 | 0.9 | 0 | 0 | 0 | 4.6 |
| | passerines | 0 | 0 | 0 | 0 | 0 | 0 | 8.4 | 6.9 | 3.9 | 5.0 | 2.9 |
| | other birds | 0.9 | 2.8 | 0 | 2.0 | 2.4 | 1.6 | 0 | 0 | 0 | 1.1 | 0.9 |

APPENDIX 1. (contd.)

| Census Dates | Birds | Transects: outer west spit | inner west spit | outer east spit | inner east spit | outer bar. isl. | inner bar. isl. | lagoon | bluff | bay | river | Mean for all transects |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8/17-8/18 | loons | 0.4 | 0 | 0 | 0 | 1.6 | 2.8 | 1.9 | 0.4 | 1.0 | 0 | 0.8 |
| | Oldsquaw | 88.2 | 0 | 138.8 | 125.6 | 252.8 | 80.0 | 0 | 9.6 | 0 | 0 | 62.3 |
| | other waterfowl | 0 | 1.1 | 0 | 2.8 | 0 | 0 | 0.3 | 0 | 8.0 | 20.8 | 4.3 |
| | shorebirds | 0 | 1.1 | 0 | 0 | 0.8 | 2.8 | 3.1 | 1.9 | 3.7 | 1.7 | 1.8 |
| | phalaropes | 20.0 | 0 | 6.4 | 0 | 10.4 | 3.6 | 0 | 0 | 0 | 0 | 3.4 |
| | passerines | 0 | 0 | 0 | 0 | 0 | 0 | 1.9 | 8.5 | 4.1 | 4.7 | 2.3 |
| | other birds | 6.4 | 0 | 0 | 8.0 | 4.8 | 0.8 | 0 | 0 | 0.5 | 3.3 | 2.2 |
| 8/21-8/22 | loons | 1.4 | 0.6 | 0.8 | 0 | 0.8 | 2.0 | 1.3 | 0 | 0 | 0 | 0.6 |
| | Oldsquaw | 33.6 | 38.9 | 16.4 | 20.4 | 97.2 | 36.0 | 0 | 0 | 0 | 0 | 20.7 |
| | other waterfowl | 0 | 0.6 | 6.8 | 0 | 0 | 0 | 21.3 | 0 | 0 | 8.1 | 4.2 |
| | shorebirds | 0 | 0.6 | 3.2 | 0.8 | 5.6 | 0 | 3.4 | 1.5 | 1.5 | 6.4 | 2.5 |
| | phalaropes | 0 | 0 | 9.2 | 0 | 8.0 | 0 | 0.3 | 0 | 0 | 0 | 1.6 |
| | passerines | 0 | 0 | 0 | 0 | 0 | 0 | 3.8 | 1.9 | 3.9 | 1.9 | 1.4 |
| | other birds | 0 | 2.2 | 0 | 0 | 0 | 0 | 0 | 0.4 | 0 | 0 | 0.2 |
| 8/25-8/27 | loons | 4.1 | 0 | 2.0 | 0.8 | 0.4 | 0 | 0.9 | 0 | 0.7 | 0 | 0.8 |
| | Oldsquaw | 115.9 | 17.8 | 64.4 | 24.0 | 201.6 | 10.4 | 44.4 | 0 | 0 | 0 | 42.9 |
| | other waterfowl | 2.7 | 8.9 | 0 | 0.4 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0.9 |
| | shorebirds | 0 | 0 | 1.6 | 0 | 6.8 | 0 | 3.1 | 0 | 0 | 2.8 | 1.5 |
| | phalaropes | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | passerines | 0 | 0 | 0 | 0 | 0 | 0 | 5.3 | 6.9 | 0.7 | 5.3 | 2.1 |
| | other birds | 2.3 | 0.6 | 0.8 | 0 | 1.6 | 0.4 | 0 | 0 | 1.5 | 6.9 | 1.6 |

APPENDIX 1. (contd.)

| Census Dates | Birds | Transects: outer west spit | inner west spit | outer east spit | inner east spit | outer bar. isl. | inner bar. isl. | lagoon | bluff | bay | river | Mean for all transects |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8/30-9/01 | loons | 0.6 | 0 | 2.0 | 1.5 | 0 | 1.3 | 0.6 | 0 | 0.2 | 0 | 0.6 |
| | Oldsquaw | 67.6 | 32.0 | 33.5 | 0 | 181.0 | 234.7 | 31.6 | 7.7 | 0 | 0 | 60.4 |
| | other waterfowl | 0.6 | 0 | 0 | 17.5 | 0 | 0 | 5.9 | 0 | 1.2 | 0 | 2.3 |
| | shorebirds | 9.4 | 15.0 | 2.0 | 38.0 | 1.7 | 13.0 | 5.3 | 0 | 3.4 | 0 | 7.1 |
| | phalaropes | 0.6 | 2.0 | 0 | 10.5 | 0 | 0 | 1.6 | 0 | 3.7 | 0 | 1.7 |
| | passerines | 0 | 0 | 0.5 | 0 | 0 | 0 | 10.9 | 1.1 | 10.2 | 18.3 | 5.6 |
| | other birds | 0 | 11.0 | 0 | 46.5 | 0.7 | 1.0 | 0.3 | 4.6 | 0.2 | 0.8 | 4.8 |
| 9/04-9/06 | loons | 8.0 | * | 4.0 | 0 | * | * | 1.3 | 0 | 0 | 0.6 | 1.2 |
| | Oldsquaw | 79.0 | * | 81.5 | 45.5 | * | * | 24.4 | 0 | 0 | 0 | 22.2 |
| | other waterfowl | 3.0 | * | 0 | 0 | * | * | 14.4 | 0 | 12.4 | 5.3 | 6.4 |
| | shorebirds | 5.0 | * | 9.5 | 1.5 | * | * | 10.6 | 0 | 0.2 | 0.3 | 3.4 |
| | phalaropes | 0 | * | 0.5 | 0 | * | * | 3.1 | 0 | 0 | 0 | 0.6 |
| | passerines | 0 | * | 0 | 0 | * | * | 1.6 | 0.4 | 2.9 | 0 | 1.0 |
| | other birds | 1.0 | * | 5.0 | 0.5 | * | * | 0.3 | 0 | 1.5 | 0.3 | 1.1 |